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Weekend/Weekday Differences in Oxidants and Their Precursors

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Differences between weekend and weekday oxidant and oxidant precursor concentrations in the Northeastern United States are examined. Statistical tests are employed to assess whether any differences in daily maximum oxidant concentrations are significant. Weekend/weekday differences in meteorology are also examined for any potential impact on weekend/weekday differences in oxidants. Oxidant concentrations are adjusted in an attempt to account for variations in meteorology, and weekend/weekday differences in the adjusted values are examined. Finally, statistical tests are used to determine significant differences in early morning oxidant precursor concentrations. The analyses revealed that oxidant concentrations downwind of major urban areas tend to be lower on weekends. However, the reductions are not as large as those observed in precursor concentrations within the major urban areas. Reductions in weekend oxidant concentrations at locations within the major urban areas are not as great as those at downwind locations.

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1. INTRODUCTION AND SUMMARY

The National Ambient Air Quality Standard (NAAQS) for photochemical oxidants (ozone) is not attained in many geographical areas, including Los Angeles, Houston, and the northeast megalopolis from Maryland to Maine. These widespread high-oxidant levels indicate the need for more comprehensive control measures for oxidant precursors than the currently implemented emission controls. To formulate a comprehensive and cost-effective control policy requires a better understanding of how sensitive ambient levels of oxidants are to changes in spatial patterns of precursor emissions, as well as to changes in amounts of precursor emissions. A study of the weekend/weekday (WE/WD) differences in oxidant and precursor concentrations would be useful for gaining a better understanding of the precursor emissions/ambient oxidant sensitivities.

The WE/WD differences in daily maximum oxidant levels have been examined by a number of researchers. In 1974, two studies conducted for different geographical regions (one for the New York-New Jersey region and the other for the Los Angeles region) reached, coincidentally, the same conclusion: That although primary-pollutant concentrations are measurably lower on weekends than on weekdays, daily maximum oxidant levels are not necessarily lower on weekends [California Air Resources Board (CARB) 1974; Cleveland et al. 1974a and 1974b]. These earlier findings were later revised when the WE/WD differences were examined for a wider geographical area and for a larger data base. Recent studies all indicate that although the oxidant level may be higher on weekends at some very-source-intensive sites, the weekend oxidant levels are measurably lower in most areas [Levitt and Chock 1975; Cleveland and McRae 1977; Elkus and Wilson 1977; Horie et al. 1977].

The present study is performed for the northeast megalopolis, extending from Washington, D.C., to Boston, Massachusetts, and uses large data bases of air quality and meteorology. The spatial pattern of the WE/WD differences, as well as that of weekday levels, is investigated for both oxidant and precursor concentrations in order to gain some insight into control strategies that are likely to be the most effective for reducing ambient levels of oxidants.

1.1 OBJECTIVES OF THIS STUDY

Despite observed reductions of ambient precursor levels on weekends, earlier studies [Cleveland et al. 1974a; CARB 1974; Elkus and Wilson 1977; and Levitt and Chock 1975] have indicated that the WE/WD differences in ambient oxidant levels are small and inconclusive. The weekend levels are higher than the weekday levels at some monitoring sites, while at other sites the weekend levels are lower or about the same. In view of these findings, the so-called weekend effect raises intriguing questions about the effectiveness of simultaneous reductions in hydrocarbons and nitrogen oxides as a policy for controlling photochemical air pollution.

The objectives of this study are as follows:

1. To determine if there are significant differences between WE and WD concentrations of precursors and oxidants;

2. To determine the extent to which these differences may be functions of meteorological variations;
3. To examine differences between WE/WD spatial and temporal patterns;
4. To assess whether further study is indicated to quantify the effectiveness of reducing oxidant levels by reducing precursor levels; and
5. To gain greater insight into control strategies that are likely to be the most effective for reducing oxidant levels.

To accomplish the above objectives, we compiled a large data base of air quality and meteorological data, including ambient pollutant concentrations at 22 sites, surface meteorological observations at 12 sites, and upper-air meteorological measurements at 3 sites. The data analysis is focused on the five summer months, May through September, during the years 1973 through 1976.

1.2 SUMMARY OF CONCLUSIONS

The paragraphs below summarize the findings and conclusions reached in this study. For convenient reference, the summary is organized according to the order of the sections.

Selection of Study Locations and Data Base Preparation (Section 2)

- Twenty-two air quality monitoring sites in and around each of the five large metropolitan areas in the northeast United States were selected for study. The five metropolitan areas are: Washington, D.C., Baltimore, Philadelphia, New York-Newark, and Boston.
- The 22 study locations represent a wide variety of site characteristics. The study sites were selected from stations upwind of, downwind of, and within the metropolitan area. However, no true rural sites are included in the analysis because of inadequate oxidant data at those sites.
- The 22 air quality monitoring sites are grouped so that sufficient weather data for the analysis can be provided by 12 surface weather stations and 3 upper-air weather stations.

- All the oxidant and precursor-pollutant data, as well as the meteorological data, were labeled as to the day of week as well as the day of year. These labels were used to compile the data for weekends and weekdays, separately.

- Two definitions of weekend/weekday are used: normal WE/WD defines weekends as Saturdays and Sundays, and weekdays as Mondays through Fridays; Sunday WE/WD defines weekends as Sundays only, and weekdays as Tuesdays through Fridays.

Difference in Daily Maximum Oxidant Levels (Section 3)

- The WE/WD differences in daily maximum oxidant levels are examined by applying two different statistical tests to the oxidant data: the t-test, and a visual test of the box-displayed WE/WD oxidant data. The final judgment on the WE/WD oxidant difference at each site is made by considering the consistency of the two test results.

- Of the 22 stations examined, only three stations--Lancaster, Pennsylvania; Greenwich, Connecticut; and Danbury, Connecticut--exhibit a consistently significant WE/WD difference by the two different statistical tests. These stations all have a significantly lower oxidant level on weekends.

- Only the Newark station exhibits a higher weekend oxidant level with marginal significance in the t-test. However, the box-display of the WE/WD oxidant data has revealed that the t-test result is probably biased by one extremely high oxidant value in the weekend data set.

- The percentage decrease in daily maximum oxidant levels on weekends is generally higher at sites downwind of the large metropolitan areas and is lower at sites within or upwind of the metropolitan areas.

- The percentage change (WE-WD) tends to be larger when Sundays are compared with Tuesday through Friday (Sunday WE/WD) than when Saturdays and Sundays are compared with Monday through Friday (normal WE/WD).

Meteorological Adjustment of WE/WD Oxidant Levels (Section 4)

- The WE/WD differences in meteorology are examined for seven meteorological variables at 12 surface meteorological stations. Of the seven variables, at least a marginally significant difference between the WE/WD levels is found in five variables at two or more meteorological stations.

- The five variables having at least a marginally significant difference are visibility, at six sites; surface pressure, at eight sites; max temperature, at two sites; wind speed, at two sites; and mixing height, at two sites.

- A pattern recognition computer program called AID was applied to find the oxidant-meteorology relationship at each air monitoring site, using weekday data only. The results are expressed in a binary classification tree, in which the relationship between daily max oxidant levels and meteorological conditions can be easily seen.

- The most important meteorological variable to explain the daily max oxidant levels is daily max temperature, which appears on 20 out of the 22 binary classification trees developed. Other important variables are visibility, on 16 trees; wind direction, on 14 trees; mixing height and wind through the mixing layer, on 10 trees; wind speed, on 8 trees; and surface pressure, on 5 trees. Average temperature never appeared, probably because of the high collinearity with max temperature.

- Three site-specific meteorological classes, high, middle, and low, were developed for each site by using the AID decision tree. WE/WD differences in daily max oxidant levels were computed for five cases: high, middle, and low meteorological classes, all days, and all days with meteorological normalization. Then, each site was categorized into one of three station types: stations showing a consistently lower weekend level among 4 out of the 5 cases; stations showing a consistently higher weekend level among 4 out of the 5 cases; and stations showing no consistent WE/WD difference among the 5 cases.

- The stations with a consistently lower weekend level among 4 out of the 5 cases are found in the periphery of or outside the large metropolitan areas; the stations with a consistently higher weekend level are found within the metropolitan areas; and the stations without a consistent WE/WD difference among the 5 cases are found in the transitional zones.

Differences in Oxidant Precursor Levels (Section 5)

- WE/WD differences in 6-9 A.M. average concentrations of NO, NO_2, and (NO_2/NO_x) are examined for eight stations reporting an adequate amount of NO and NO_2 data for the analysis. The eight stations are Bethesda, Silver Spring, Suitland, and Baltimore in Maryland; Camden and Newark in New Jersey; Welfare Island and Mamaroneck in New York.

- Five stations, Silver Spring, Baltimore, Camden, Newark, and Mamaroneck, exhibit a significantly lower 6-9 A.M. average NO level on weekends. One station, Bethesda, shows a higher weekend NO level with marginal significance. The remaining two stations, Suitland and Welfare Island, do not show a significant WE/WD difference in 6-9 A.M. NO concentrations.

- For 6-9 A.M. average NO_2 concentrations, all eight stations examined exhibit a significantly lower level on weekends than on weekdays.

- The WE/WD difference in 6-9 A.M. nonmethane hydrocarbons (NMHC) and total hydrocarbons (THC) is examined for six stations. Among the four stations examined for NMHC, the Baltimore and Suitland stations exhibit a significantly lower weekend level under the Sunday WE/WD definition. Under the normal WE/WD definition, all four stations showed a significantly lower weekend level. The two stations, Bethesda and Camden, examined for THC under the normal WE/WD definition showed a significantly lower weekend level.

- The WE/WD difference in carbon monoxide (CO) was examined for 17 stations under the normal WE/WD definition. All but two stations exhibit significantly lower 6-9 A.M. concentrations on weekends.

- The results of the analyses indicate that 6-9 A.M. primary-pollutant concentrations of NO_x, NMHC, THC, and CO are indeed lower on weekends than on weekdays.

Results and Conclusions (Section 6)

- The average oxidant improvement on weekends is 9% when Sundays are compared with Tuesday through Friday (Sunday WE/WD), and 5% when Saturdays and Sundays are compared with Monday through Friday (normal WE/WD).

- A greater oxidant improvement (11% to 12%) is observed in areas downwind of the large metropolitan areas than in the source-intensive urban core areas.

- The oxidant improvement (5% to 12%) on weekends is small compared with the 40% to 50% reductions in 6-9 A.M. urban NO_x and NMHC levels on weekends. However, the weekend reductions in daytime and 24-hr precursor levels appear to be considerably smaller than those in 6-9 A.M. precursor levels.

- The small oxidant improvement on weekends, brought about by simultaneous reductions in NO_x and NMHC, may be an indication that the simultaneous control of NO_x and NMHC is less effective for controlling urban oxidants than are hydrocarbon controls.

2. SELECTION OF STUDY LOCATIONS AND DATA BASE PREPARATION

The areas in this study encompass the entire northeast megalopolis from Washington, D.C., to Boston, Massachusetts. Although cities and towns are scattered throughout the 400-mile-long study region along the Atlantic Coast, a great concentration of the population is found in the five large metropolitan areas (Figure 1): Washington, D.C., Baltimore, Philadelphia, New York-Newark, and Boston. According to the 1970 SMSA population summary [U.S. Commerce Dept. 1973], the study region contains a population of well over 26 million people (New York = 11.6, Philadelphia = 4.8, Washington, D.C. = 2.9, Boston = 2.8, Baltimore = 2.1, and Newark = 1.9 million people).

Ambient air monitoring data [U.S. EPA 1977] and special studies [Ludwig and Skelar 1977; Wight et al. 1977; Wolff et al. 1977; Cleveland 1976] indicate high-oxidant air pollution over the study region. To study the response characteristics of photochemical oxidants to changes in precursor-pollutant levels between weekends and weekdays, we compiled a large data base of air quality and meteorological data. The air quality data include not only oxidant (OX) concentration data (measured as ozone), but also concentration data of nitric oxide (NO), nitrogen dioxide (NO_2), oxides of nitrogen (NO_x), total hydrocarbons (THC), nonmethane hydrocarbons (NMHC), and carbon monoxide (CO). The meteorological data include both surface meteorological observations and upper-air meteorological observations. Because high-oxidant air pollution occurs primarily in the summer season, the air quality and meteorological data were compiled for the five warmer months (May through September) of the years 1973 through 1976.

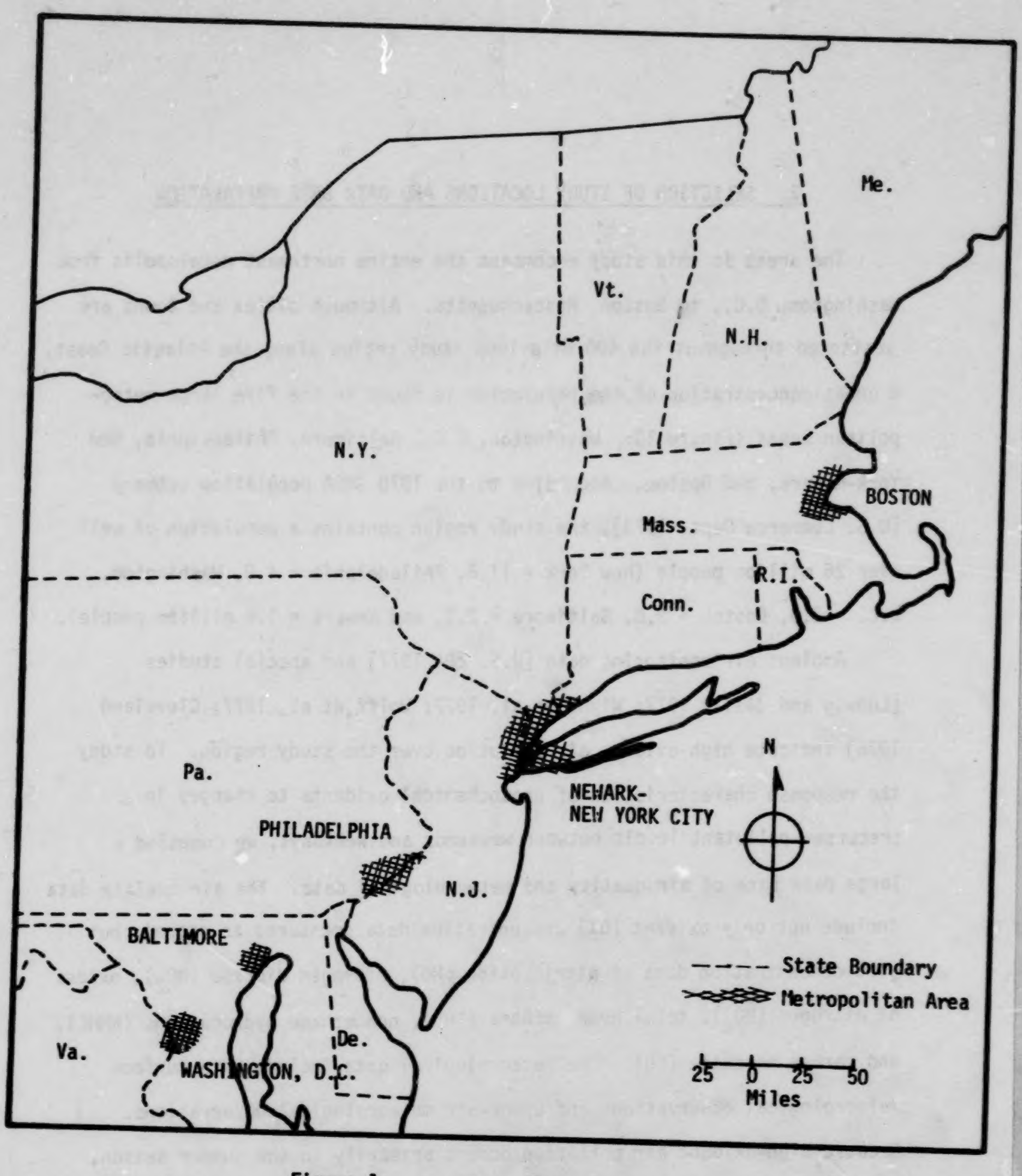
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Figure 1. Map of the northeastern United States, showing the five large metropolitan areas selected for the WE/WD air quality analysis.

2.1 AIR QUALITY DATA

After considering the data completeness of hourly oxidant and precursor concentration data during the study period, 22 oxidant monitoring stations were selected from the areas in and around the five large metropolitan areas (Figure 1). Table 1 provides the station name, the EPA's SAROAD I.D. code, the site type, and the number of valid observation days for each of the 22 stations used for the oxidant air quality analysis. These stations were chosen such that the WE/WD differences could be examined in areas upwind of, within, and downwind of each of the five metropolitan areas. The geographical locations of these monitoring stations are shown in Figure 2 by the abbreviated station names; full station names can be found in Table 1.

Precursor concentration data are less complete than the oxidant data. As a result, fewer monitoring stations are used for the analysis of precursor-pollutant data. Adequate NO and NO_2 data are found at eight stations: Bethesda (BE), Silver Spring (SS), Suitland (SU), Baltimore (BA), Camden (CA), Newark (NE), Welfare Island (WI), and Mamaroneck (MA) (see Figure 2 for their location). NO_x data at these sites are computed by summing NO and NO_2 concentration values. Adequate NMHC data are found at four stations only: Silver Spring, Suitland, Baltimore, and Norristown. Only two stations, Bethesda and Camden, are used for the analysis of THC concentration data.

CO was also analyzed because in many cases it can be used as an indicator of automotive-related pollutant levels.

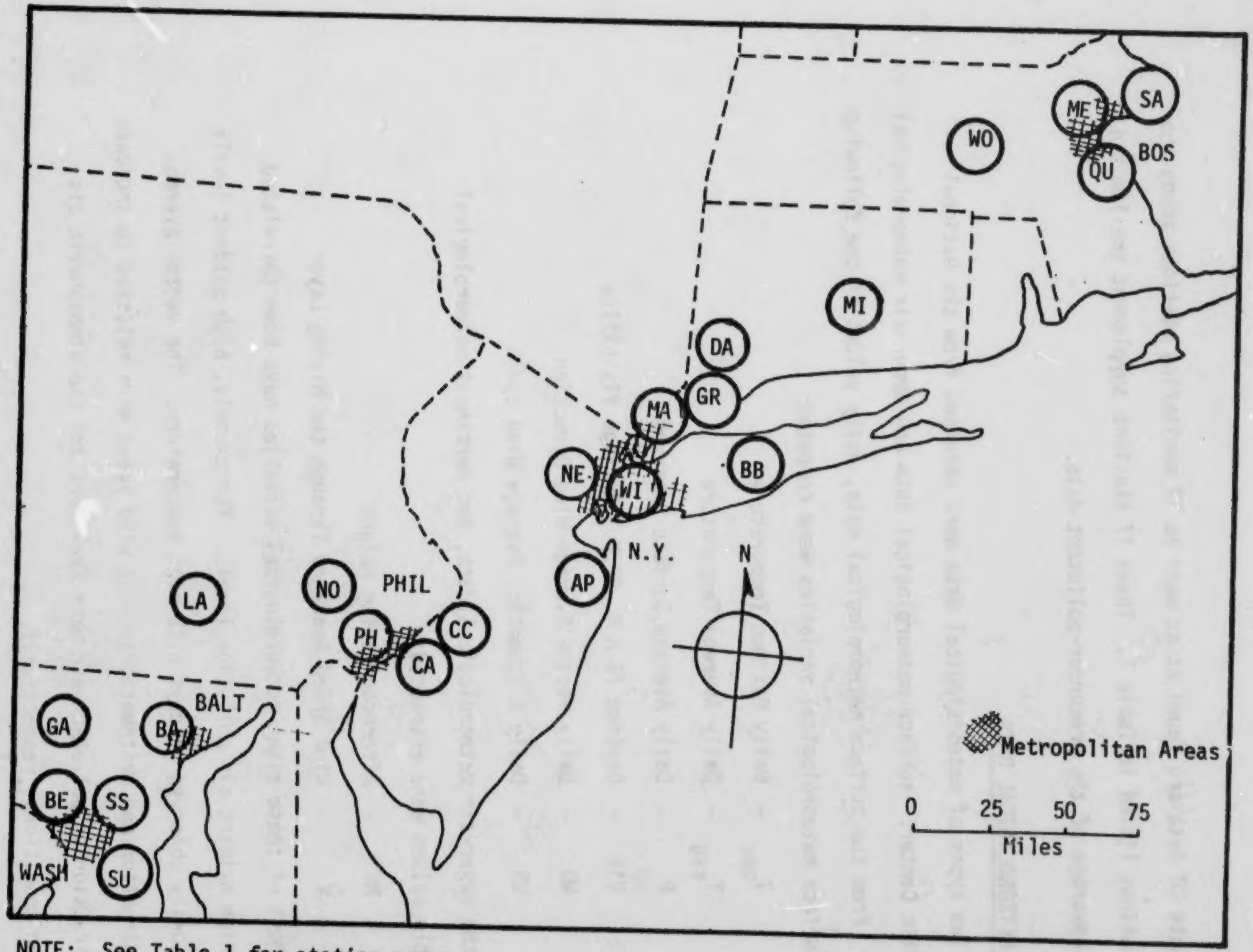
TABLE 1. MONITORING STATIONS USED FOR ANALYZING OXIDANT AIR QUALITY DATA

Metropolitan Area	Station Name	SAROAD I.D.	EPA's Site Code*	Number of Valid Observation Days†
Washington, D.C.	Bethesda (BE)	210200005 F01	S-R	286
	Gaithersburg (GA)	210780004 G01	S-R	140
	Silver Spring (SS)	211480006 F01	S	248
	Suitland (SU)	211560001 F01	S	351
Baltimore	Baltimore (BA)	210120018 F01	CC-C	253
	Lancaster (LA)	394660007 F01	S-R	232
Philadelphia	Camden (CA)	310720003 F01	S-R	371
	Camden Co. (CC)	310740001 F01	Ru-A	224
	Norristown (NO)	396540013 F01	S-R	230
	Philadelphia (PH)	397140026 H01	CC-C	251
Newark - New York	Asbury Park (AP)	310060001 F01	CC-C	197
	Babylon (BB)	330280002 F01	S-I	238
	Danbury (DA)	070175123 F01	CC-R	250
	Greenwich (GR)	070330004 F01	Ru-NU	340
	Mamaroneck (MA)	334100002 F01	CC-C	377
	Middletown (MI)	070570003 F01	CC-I	284
	Newark (NE)	313480002 F01	CC-C	278
	Welfare Is. (WI)	334680050 F01	CC	362
Boston	Medford (ME)	221220003 F01	S-I	415
	Quincy (QU)	221880002 F01	S-I	458
	Salem (SA)	221980001 F01	S-R	184
	Worchester (WO)	222640012 F01	CC-C	350

*Code key:

A - Agricultural
C - Commercial
CC - Center City
I - Industrial
R - Residential
Ru - Rural
S - Suburban
NU - Near-Urban

†A "valid observation day" is defined as a day having at least 10 observations for the period 6 A.M.-9 P.M., with the maximum hourly concentration not exceeding 50 ppb after 9 P.M. and before 6 A.M.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NOTE: See Table 1 for station names.

Figure 2. Location of 22 monitoring stations used for the WE/WD oxidant air quality analysis.

Adequate CO data are found at as many as 17 monitoring stations among the 22 stations listed in Table 1. These 17 stations supplement the limited area coverage of the precursor-pollutant data.

2.2 METEOROLOGICAL DATA

Two types of meteorological data were obtained from the National Climatic Center: surface meteorological data and upper-air meteorological data. From the surface meteorological data, daily values of the following six surface meteorological variables were computed:

T_{max} - Daily Maximum Temperature

T_{avg} - Daily Average Temperature

P - Daily Average Surface Pressure

Vis - Daytime (6 A.M.-9P.M.) Average Visibility

WD - Daily Vector Average Wind Direction

WS - Daily Arithmetic Average Wind Speed

From the upper-air meteorological data, two pertinent meteorological variable values were extracted:

MH - Afternoon Mixing Height

$\bar{V}$ - Wind Speed Averaged Through the Mixing Layer

Most of these eight meteorological variables have been correlated with high oxidant air pollution levels. For example, high oxidant levels are usually observed on days with high temperature. The vector average wind direction and arithmetic average wind speed were selected to indicate the direction of pollutant air mass transport and the atmospheric dispersion conditions, respectively.

Table 2 lists the three upper-air and 12 surface stations at which the meteorological data used in this analysis were collected. The geographical locations of the three upper-air meteorological stations, 12 surface meteorological stations, and 22 air monitoring stations are depicted in Figure 3 with three different symbols. The name and I.D. number of each station are listed in Table 2. The circles and dashed lines in the figure indicate how each air monitoring site is grouped to a nearby surface meteorological station and to one of the three upper-air meteorological stations. The groupings of these stations are given in Table 2.

TABLE 2. METEOROLOGICALLY GROUPED AIR MONITORING STATIONS

Air Monitoring Station	SAROAD I.D.	Surface Met. Station	(Station No.)	Upper-Air Met Station (Station No.)
Medford Quincy Salem	221220003 F01 221880002 F01 221980001 F01	Boston, Mass.	(14739)	J.F. Kennedy (94789)
Worchester	222640012 F01	Worchester, Mass.	(94746)	
Middletown	070570003 F01	Windsor Locks, Conn.	(14740)	
Danbury Greenwich	070175123 F01 070330004 F01	Bridgeport, Conn.	(94702)	
Mamaroneck Welfare Is.	334100002 F01 334680050 F01	La Guardia, N.Y.C.	(14732)	
Babylon	330280002 F01	J. F. Kennedy, N.Y.C.	(94789)	
Newark	313480002 F01	Newark, N.J.	(14734)	
Asbury Park	310060001 F01	Atlantic City, N.J.	(93730)	
Camden Camden Co. Norristown Philadelphia	310720003 F01 310740001 F01 396540013 F01 397140026 H01	Philadelphia, Pa.	(13739)	Wash., D.C. (13743)
Baltimore	210120018 F01	Baltimore, Md.	(93721)	
Bethesda Gaithersburg Silver Spring Suitland	210200005 F01 210780004 G01 211480006 F01 211560001 F01	Washington, D.C. (National)	(13743)	
Lancaster	394660007 F01	Harrisburg, Pa.	(14751)	Albany, N.Y. (14735)

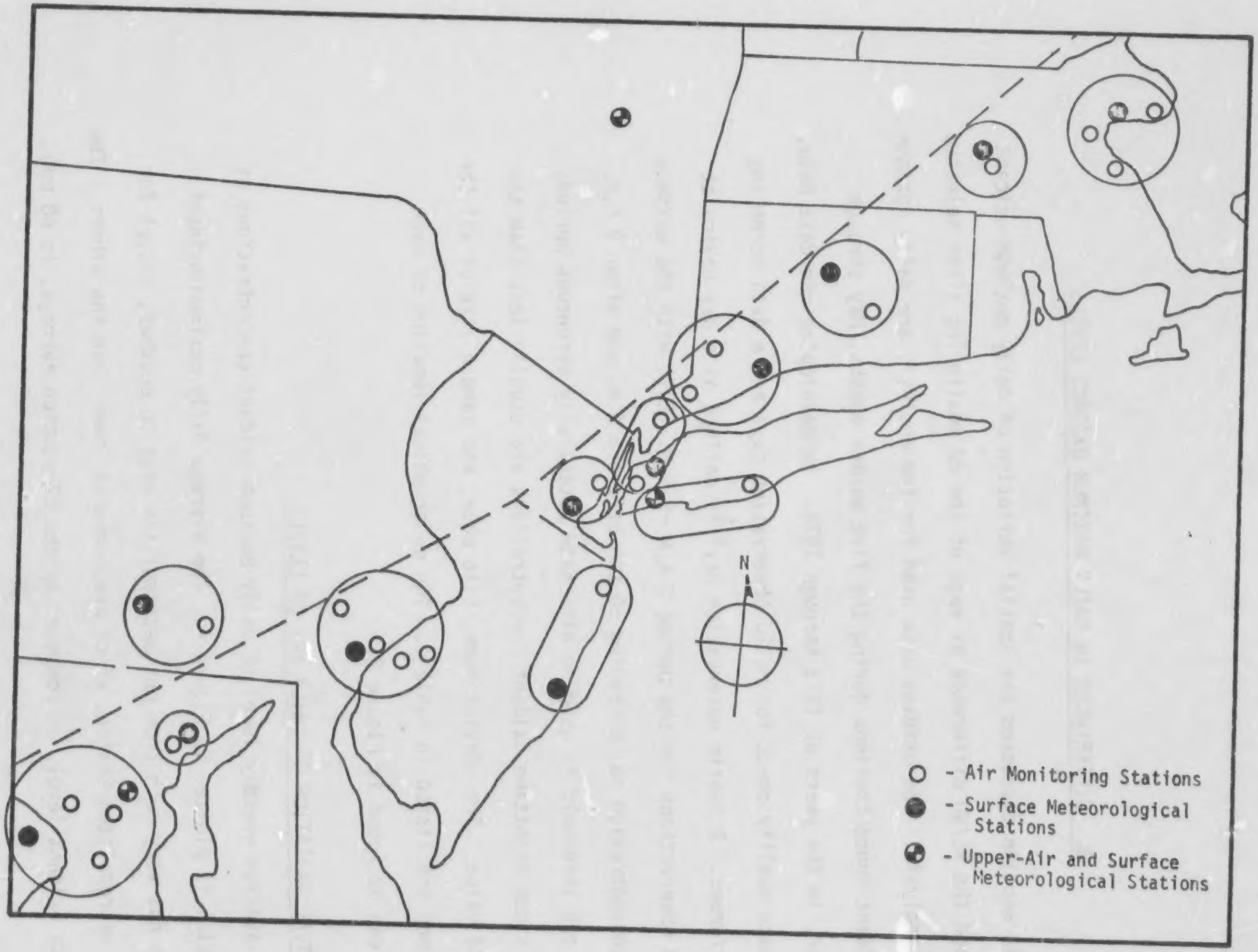

N
○ - Air Monitoring Stations
● - Surface Meteorological Stations
● - Upper-Air and Surface Meteorological Stations

Figure 3. Location of 22 air monitoring stations, 12 surface meteorological stations, and 3 upper-air meteorological stations used for the analysis. [Several air monitoring stations are grouped to a nearby surface meteorological station (in circle) which is, in turn, grouped to one of the three upper-air meteorological stations (dashed line).]

3. DIFFERENCES IN DAILY MAXIMUM OXIDANT LEVELS

This section discusses the spatial variation of daily maximum oxidant levels and the WE/WD difference at each of the 22 monitoring sites selected for the analysis. The oxidant data used for the analysis are daily maximum 1-hr oxidant concentrations during the five warmer months, May through September, in the years of 1973 through 1976. In developing the data base, both a data quality check for valid observation days and a data screening were performed. A "valid observation day" is defined as a day having at least 10 observations for the period 6 A.M.-9 P.M. (EDT) with the maximum hourly concentration not exceeding 50 ppb before 6 A.M. and after 9 P.M. (The 50 ppb threshold is used to eliminate potentially erroneous periods of data since nighttime oxidant concentrations are usually less than the threshold value. The station name, site code, and sample size of all the 22 stations are listed in Table 1. The geographical location of each station can be found in Figure 2.

3.1 SPATIAL VARIATION OF DAILY MAX OX LEVELS

The average weekday level of daily maximum oxidant concentrations at each station is plotted in Figure 4. The average daily maximum oxidant levels do not vary much from one metropolitan area to another, except for those of metropolitan Boston, which are somewhat lower than the others. The regionwide oxidant level, as computed by the 22-station average, is 68 ppb.

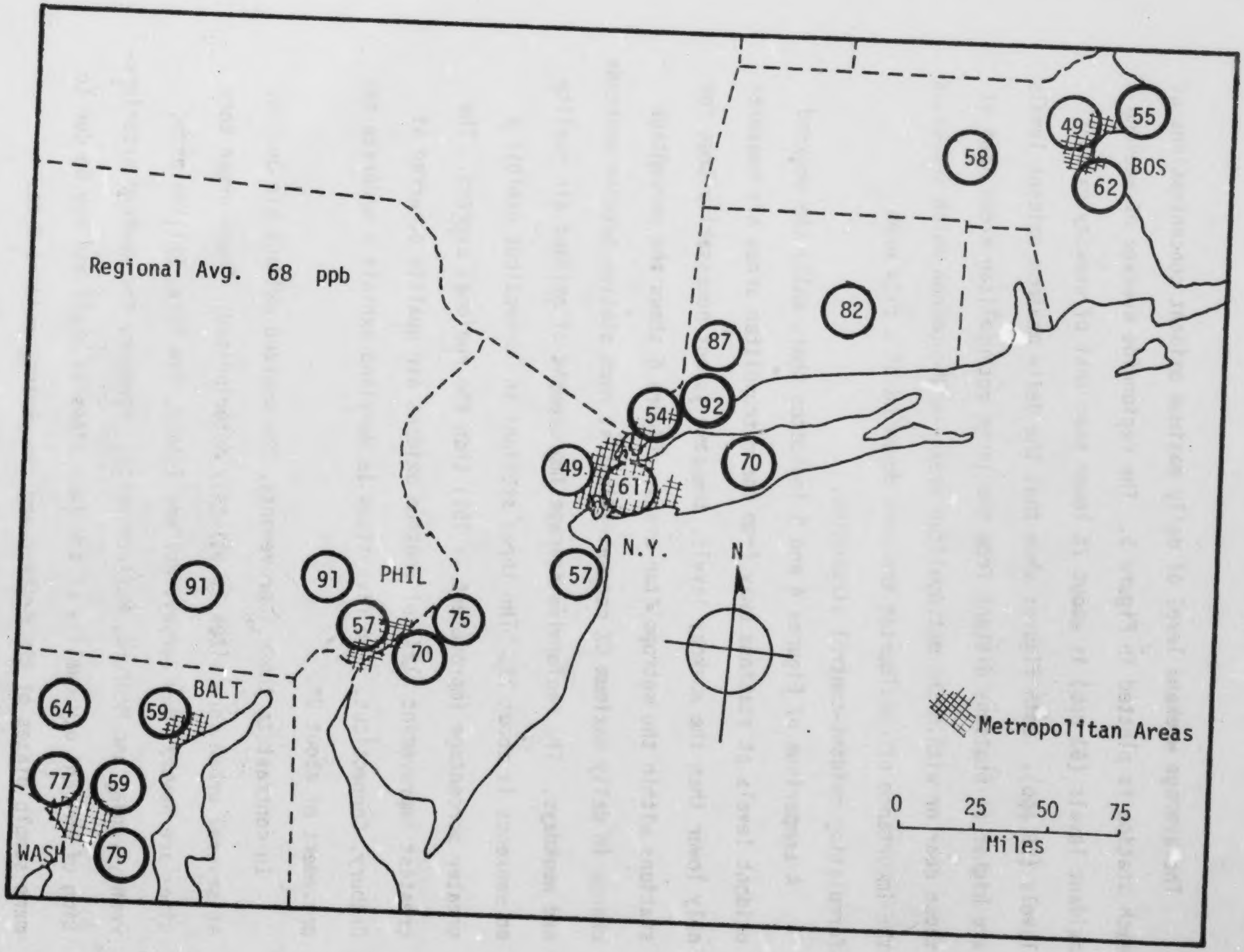

Regional Avg. 68 ppb
55
49
BOS
62
58
82
87
92
54
70
49
61
N.Y.
57
N
91
91
PHIL
57
75
70
64
59
BALT
77
59
79
WASH
Metropolitan Areas
0
25
50
75
Miles

Figure 4. Mean weekday levels of daily maximum OX concentrations (weekdays as Monday through Friday).

The average weekend level of daily maximum oxidant concentrations at each station is plotted in Figure 5. The regionwide average of weekend oxidant levels (63 ppb) is about 7% lower than that of weekday oxidant levels (68 ppb). Both figures show that the daily maximum oxidant levels are higher at stations distant from the large metropolitan areas than at those near or within the metropolitan areas--a phenomenon which indicates the importance of considering the area downwind of a city when formulating oxidant-control strategies.

A comparison of Figures 4 and 5 indicates that, while the weekend oxidant levels at stations away from the metropolitan areas are measureably lower than the weekday levels, the same is not necessarily true for stations within the metropolitan areas. Figure 6 shows the percentage change in daily maximum OX concentrations at each station between weekends and weekdays. The regionwide average improvement of oxidant air quality on weekends is about 7%. The three stations in Connecticut exhibit a greater percentage improvement (≈ 15%) than the regional average. The greatest improvement (18%) of weekend oxidant air quality occurred at Danbury, Connecticut. The five sites in Maryland exhibit a moderate improvement of about 9%.

In contrast to these improvements, the weekend oxidant air quality at several urban core sites is slightly deteriorated. These urban core sites are Newark, New Jersey; Welfare Island, New York; Philadelphia, Pennsylvania; and Medford, Massachusetts. However, the weekend deterioration of oxidant air quality at the four sites is small and may be due to mere sample biases of the weekend and the weekday oxidant data.

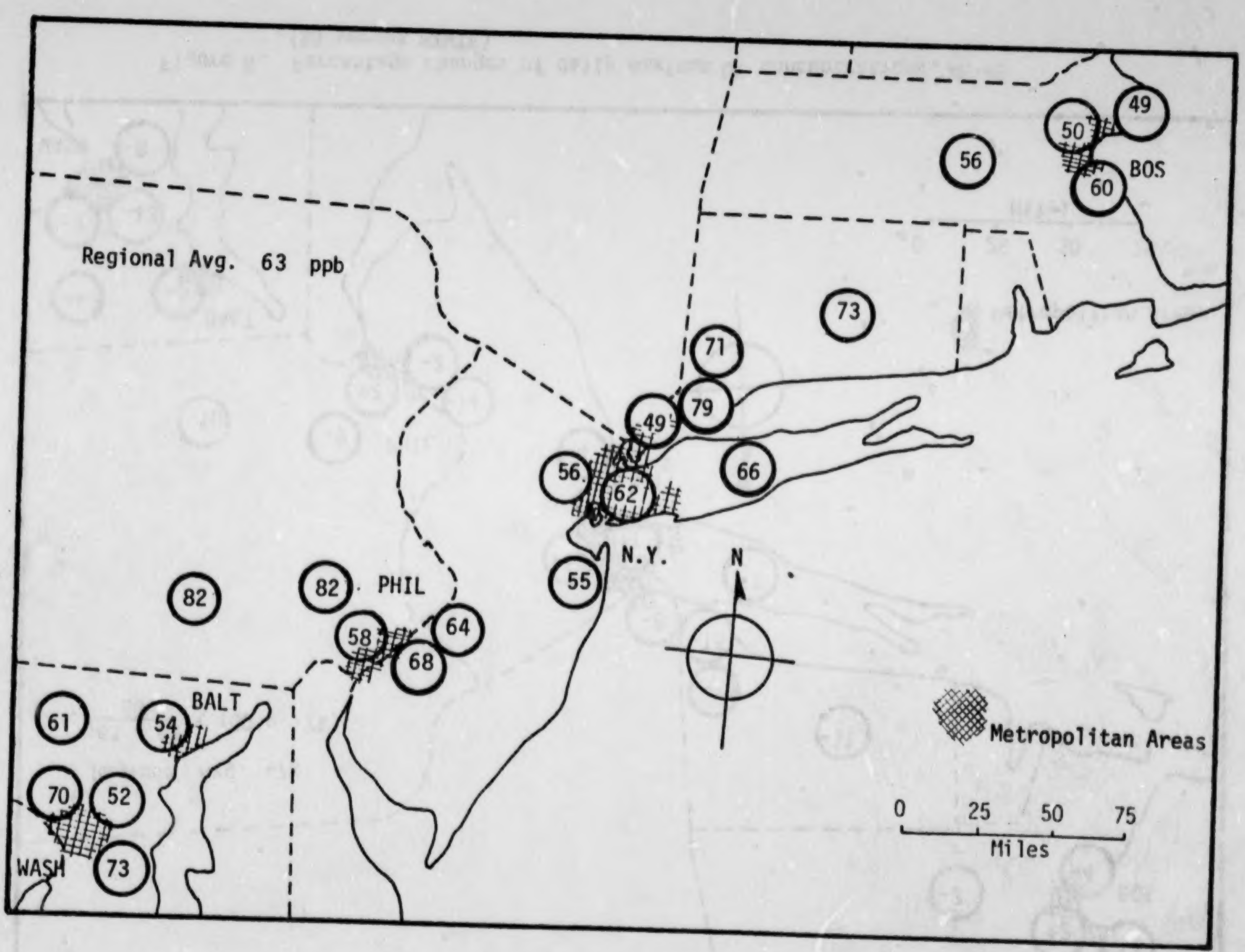

Regional Avg. 63 ppb
49
50
60
BOS
56
73
71
79
49
66
56
62
N.Y.
55
N
82
82
PHIL
58
64
68
61
54
BALT
70
52
73
WASH
Metropolitan Areas
0
25
50
75
Miles

Figure 5. Mean weekend levels of daily maximum OX concentrations (weekends as Saturday and Sunday).

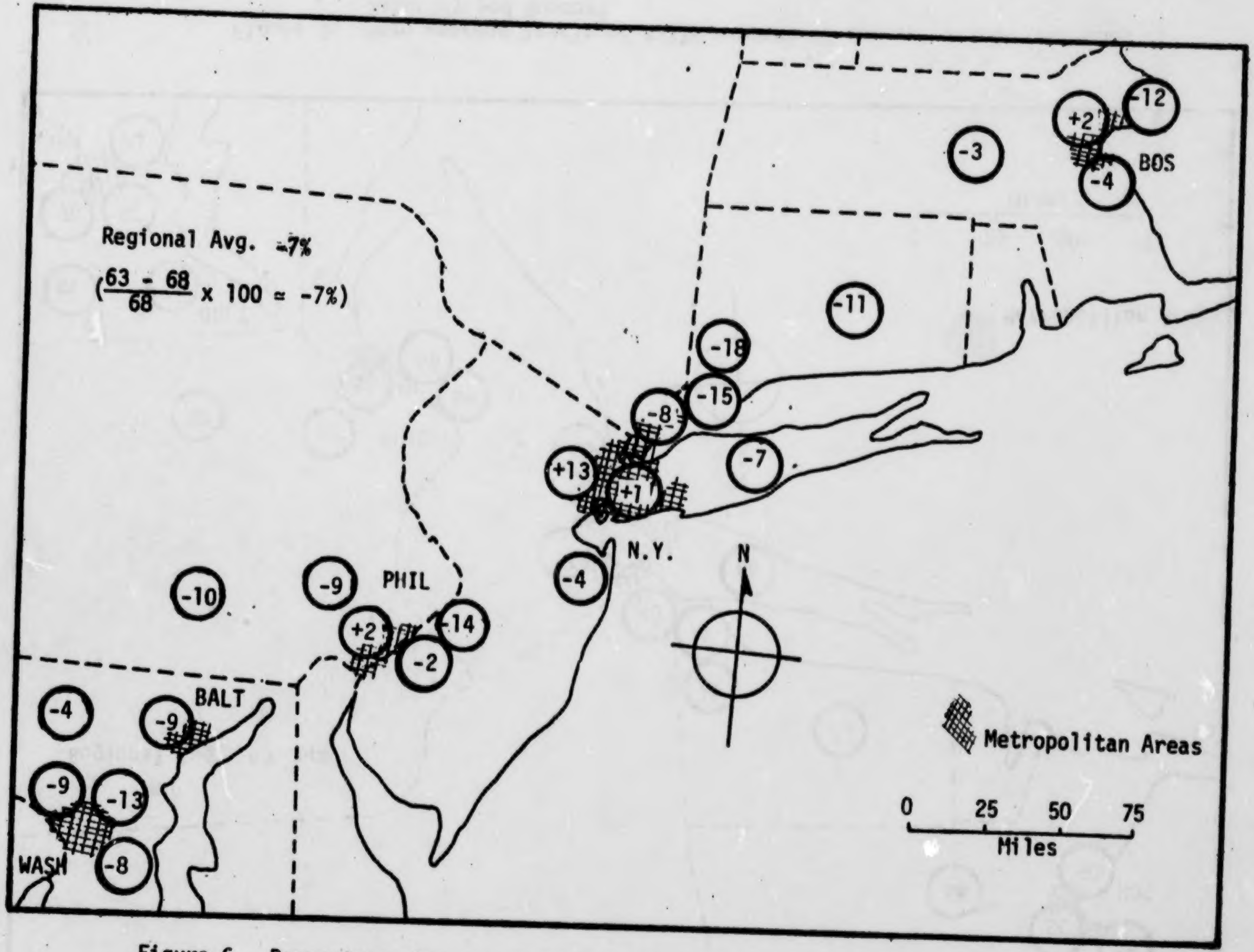

-12
+2
BOS
-4
-3
Regional Avg. -7%
($\frac{63 - 68}{68}$ x 100 ≃ -7%)
-11
-18
-15
-8
-7
+13
+1
N.Y.
N
-4
-10
-9
PHIL
-14
+2
-2
BALT
-4
-9
-9
-13
WASH
-8
Metropolitan Areas
0
25
50
75
Miles

Figure 6. Percentage changes of daily maximum OX concentrations, WE-WD (SS versus MTWTF).

Figure 7 shows the percentage changes in daily maximum oxidant levels when the oxidant levels on Sunday are compared with those on Tuesday through Friday (TWTF). The percentage decrease on Sundays (Figure 7) appears to be generally greater than that on Saturdays and Sundays combined (Figure 6). Indeed, the regional average percentage reduction on weekends is increased slightly from 7% to 10% when Sundays are compared with Tuesdays through Fridays.

The next subsection examines the significance of the WE/WD differences depicted in Figures 6 and 7.

3.2 WE/WD DIFFERENCES IN DAILY MAX OX LEVELS

This subsection examines the significance of the WE/WD differences observed in daily maximum oxidant data by applying several different statistical methods to the original data. A weekend is normally defined as Saturday and Sunday (SS) and a weekday as any day from Monday through Friday (MTWTF). However, it has been noted that the oxidant behavior on Saturdays and Mondays may be somewhat influenced by the carryover effect from the preceding day. Therefore, statistical testing methods are also applied to the data set of the other WE/WD definition that treats a weekend as Sunday only (Sun.) and a weekday as any day from Tuesday through Friday (TWTF). To distinguish between the two definitions, the SS weekend and MTWTF weekday will be referred to as the normal WE/WD, and the Sunday-only weekend and the TWTF weekday will be designated the Sunday WE/WD.

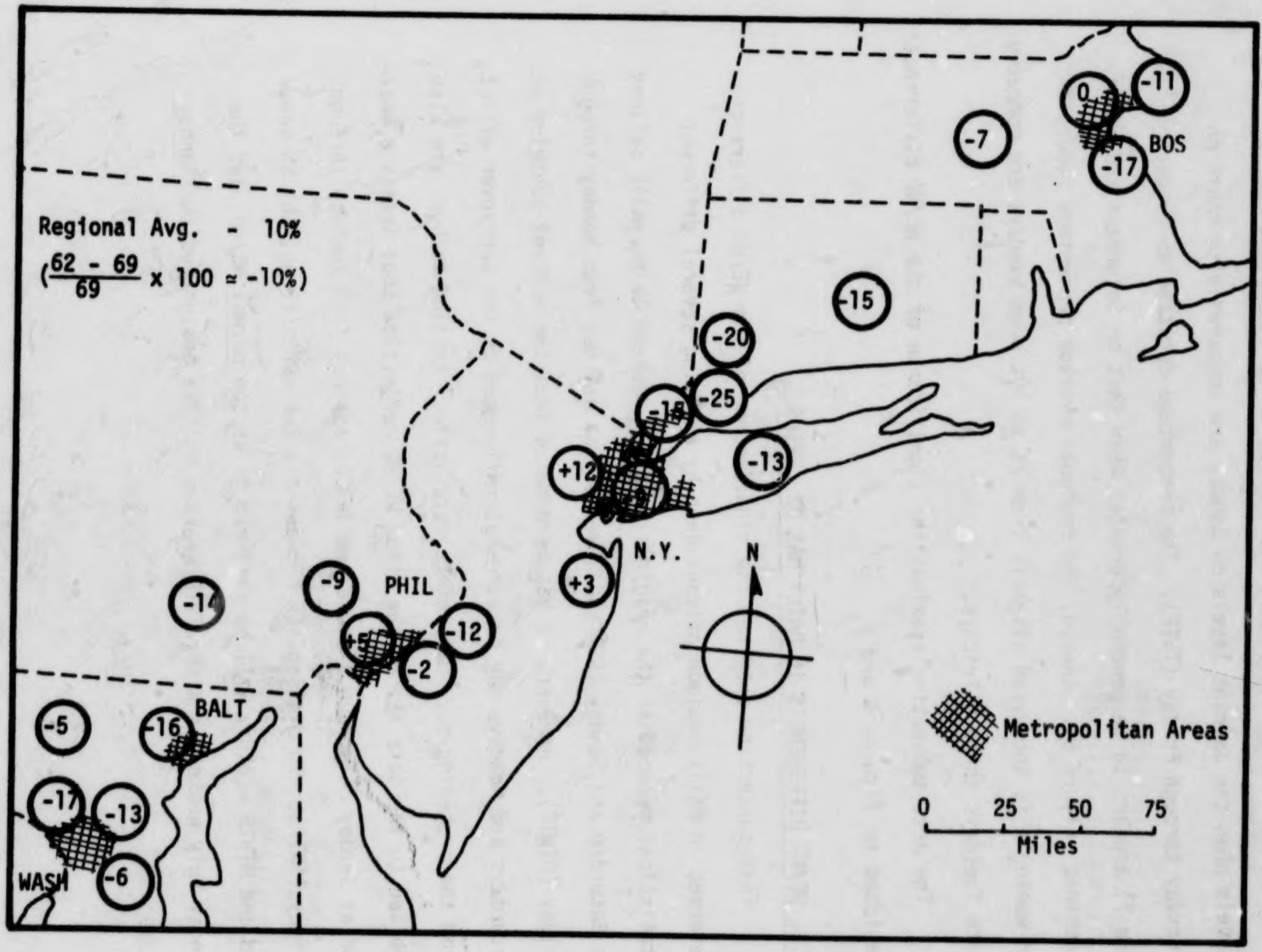

Regional Avg. - 10%
(62 - 69 / 69 x 100 ≈ -10%)
BOS
0
-11
-17
-7
-15
-20
-25
-13
+12
N.Y.
+3
N
-9
PHIL
-12
+5
-2
-14
BALT
-16
-5
-17
-13
-6
WASH
Metropolitan Areas
0
25
50
75
Miles

Figure 7. Percentage changes of daily maximum OX concentrations, WE-WD (Sun. versus TWTF).

The statistical t-test is employed to determine if the WE/WD difference observed in the mean daily maximum oxidant data is due to mere chance (see Appendix A). The t-test is applied to the two data sets derived from the normal and Sunday WE/WD definitions. The results of the t-test are plotted in Figure 8 by using the P-value corresponding to the value T of the t-test statistics. A small P-value, say, $P \leq 0.05$, indicates that the difference in the two means (WE and WD oxidant levels) is real and significant. A moderate P-value, $0.05 < P \leq 0.10$, implies that the difference between the WE/WD levels is likely to be real but yet may be due to mere chance. The larger the P-value, the more likely that the observed WE/WD difference is caused by mere chance and thus is not significant.

Under the normal WE/WD definition, four stations--Lancaster, Pennsylvania; Camden County, New Jersey; Danbury, Connecticut; and Greenwich, Connecticut--exhibit a statistically significant difference between the WE and WD daily maximum oxidant levels (Figure 8). Under the Sunday definition, three stations, Danbury, Greenwich, and Quincy, show a significant difference. All these stations have considerably lower oxidant levels on weekends than on weekdays. Several other stations show a marginally significant WE/WD difference in daily maximum oxidant under either the normal or the Sunday definition. Among them, only the Newark station exhibits a higher weekend oxidant level. However, the weekend levels at the Newark station are only significantly higher than the weekday levels under the normal WE/WD definition.

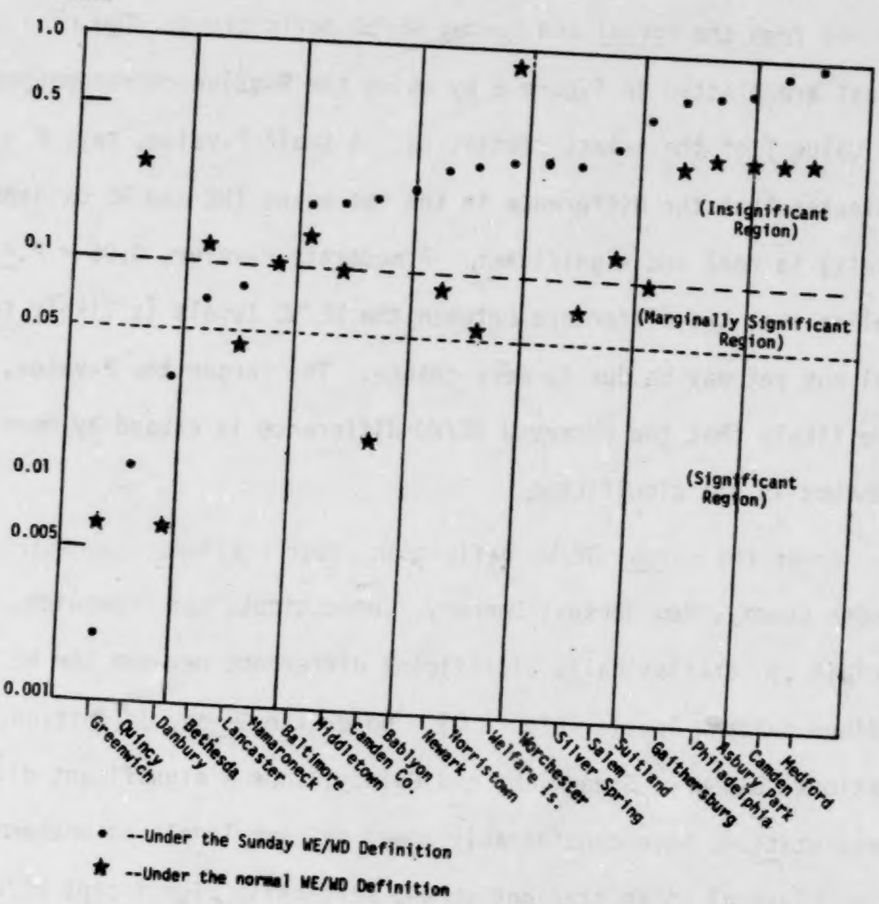


Figure 8. Plot of P-values for testing the WE/WD difference in daily maximum oxidant levels.

Note that in most cases, the P-values are larger for the Sunday WE/WD definition than for the normal definition, implying that the Sunday WE/WD differences are less significant than the normal WE/WD differences. However, these larger P-values are primarily due to the smaller sample size associated with the Sunday WE/WD data set. As can be seen from Figures 6 and 7, the percentage difference between weekends and weekdays is greater under the Sunday WE/WD definition for most of the stations.

To confirm the t-test results, we employed a visual test comparing box-displayed data, seeking consistency of the two results. The box-display presents, graphically, several pertinent statistical parameters of the data: the sample size, median value, 25th and 75th percentiles, first- and second-highest values, and lowest value. The box-display of data is more descriptive than the usual presentation of mean, standard deviation, and t-statistics. Also, the median, which is less affected by outlying data points than the mean, provides a more robust means of comparing WE/WD differences.

First, the box-display method is applied to the stations that exhibit a higher oxidant level on weekends under at least one of the two WE/WD definitions. These stations are Newark, Welfare Island, Philadelphia, Medford, and Asbury Park (see Figures 6 and 7). Figure 9 demonstrates the box-display for the WE/WD daily maximum oxidant concentrations at Newark, New Jersey. Although the Newark station

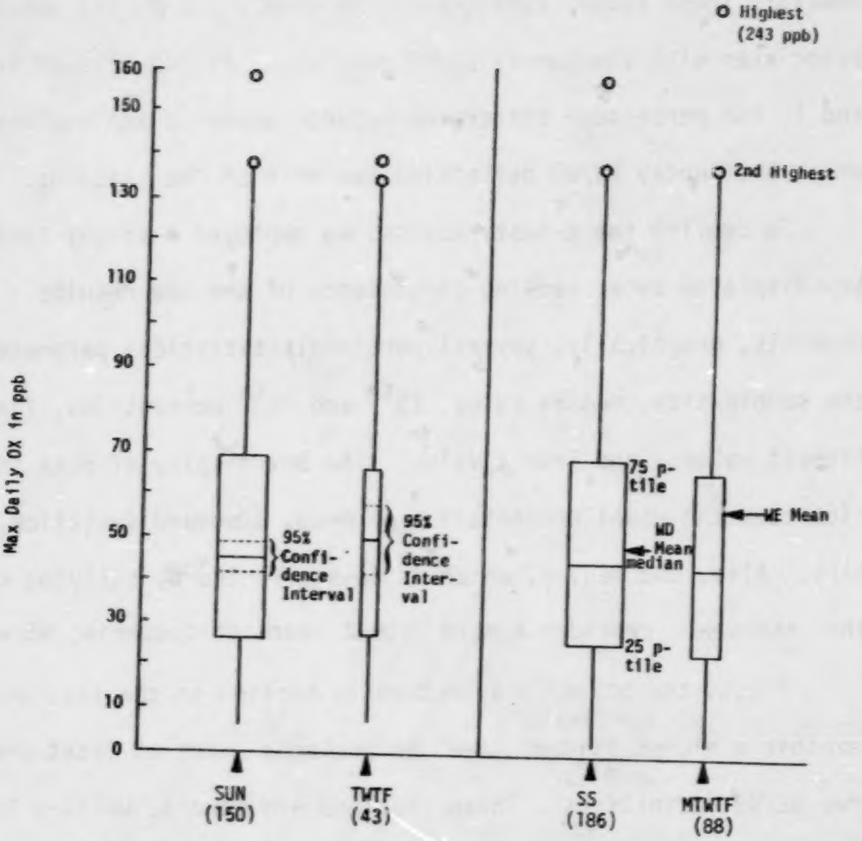
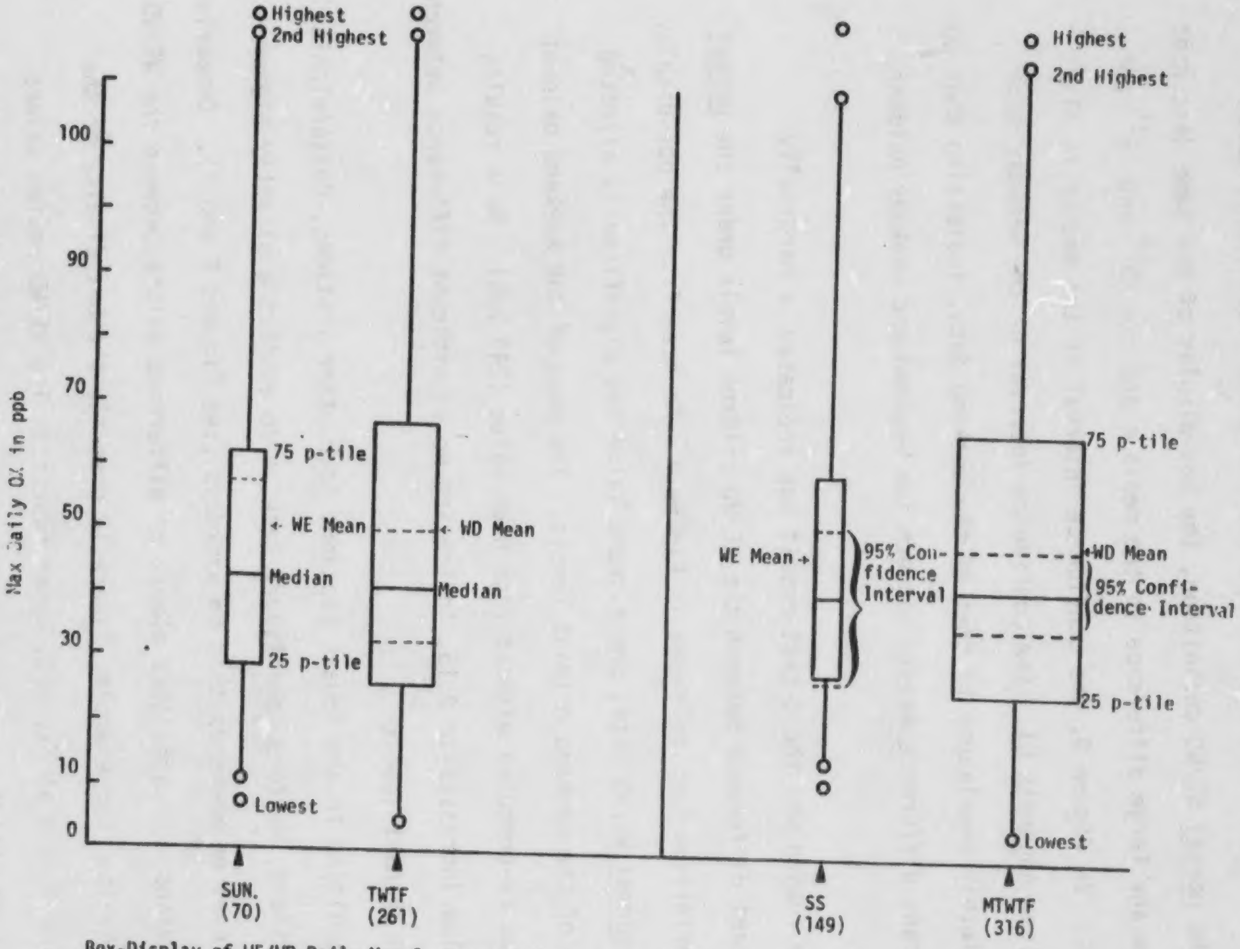


Figure 9. Box-display of WE/WD daily maximum oxidant concentrations--under normal and Sunday definitions--for the Newark, New Jersey, site.

exhibits a higher weekend oxidant level with marginal significance under the normal WE/WD definition, the box-display of the same data does not show any large difference in the medians and the 25th and 75th percentiles. In Figure 9, the confidence interval of the median is also shown (see Appendix C). The confidence interval of the weekday data is completely overlapped by that of the weekend data, indicating that no significant difference exists between the weekend and weekday oxidant levels.

One reason why the t-test result has indicated a marginally significant difference between the WE/WD oxidant levels under the normal WE/WD definition can be found in Figure 9. As seen from the box-display for the normal WE/WD data, one extreme value has significantly affected the mean of the weekend oxidant levels. The mean of the weekend oxidant levels was re-computed without this high value (243 ppb). As a result, the P-value increases to 0.15, indicating no significant difference between the WE/WD oxidant levels.

In addition to the Newark station, four other stations, Philadelphia, Welfare Island, Medford, and Asbury Park, also exhibit a slightly higher oxidant level on weekends than on weekdays (see Figures 6 and 7). Comparison of the medians indicates that almost no difference exists between the WE/WD oxidant levels. For example, Figure 10 presents the box-display of the WE/WD oxidant data at Medford, Massachusetts. The WE/WD median values are almost identical, and the WE confidence interval overlaps that of the WD.



Box-Display of WE/WD Daily Max O_x Concentrations at Medford Site.

Figure 10. Box-display of WE/WD daily maximum oxidant concentrations--under normal and Sunday definitions--for the Medford, Massachusetts, site.

Next, the box-display method was applied to the stations that exhibit a lower oxidant level on weekends in both Figures 6 and 7. Figure 11 shows the box-display of the WE/WD oxidant data at Greenwich, Connecticut, where the t-test result exhibits significantly lower weekend oxidant levels under the normal and the Sunday WE/WD definitions (see Figure 7). The box-display shows that the median of the weekend oxidant levels is significantly lower than that of the weekday levels under both the normal and Sunday WE/WD definitions. Furthermore, the confidence intervals of the two medians are completely separated from each other, indicating that a significant difference exists between the weekend and weekday oxidant levels.

Similarly, a clear separation of the confidence intervals of the two medians is observed in the box-displayed data for the WE/WD daily maximum oxidant levels at the Danbury and Lancaster stations. At the Camden County station, such clear separation occurs only in the SS vs. MTWTF comparison. The box-displayed data for Bethesda, Silver Spring, Suitland, Norristown, Middletown, and Quincy all failed to show a significant difference, although the t-test results for those stations showed at least a marginally significant difference under one of the two WE/WD definitions. The rest of the stations do not exhibit a significant difference in either the t-test results or the box-displayed data.

The results of the significance test for the WE/WD difference in daily maximum oxidant levels are summarized in Table 3. The t-test results are categorized by three levels: significant, marginally significant, and

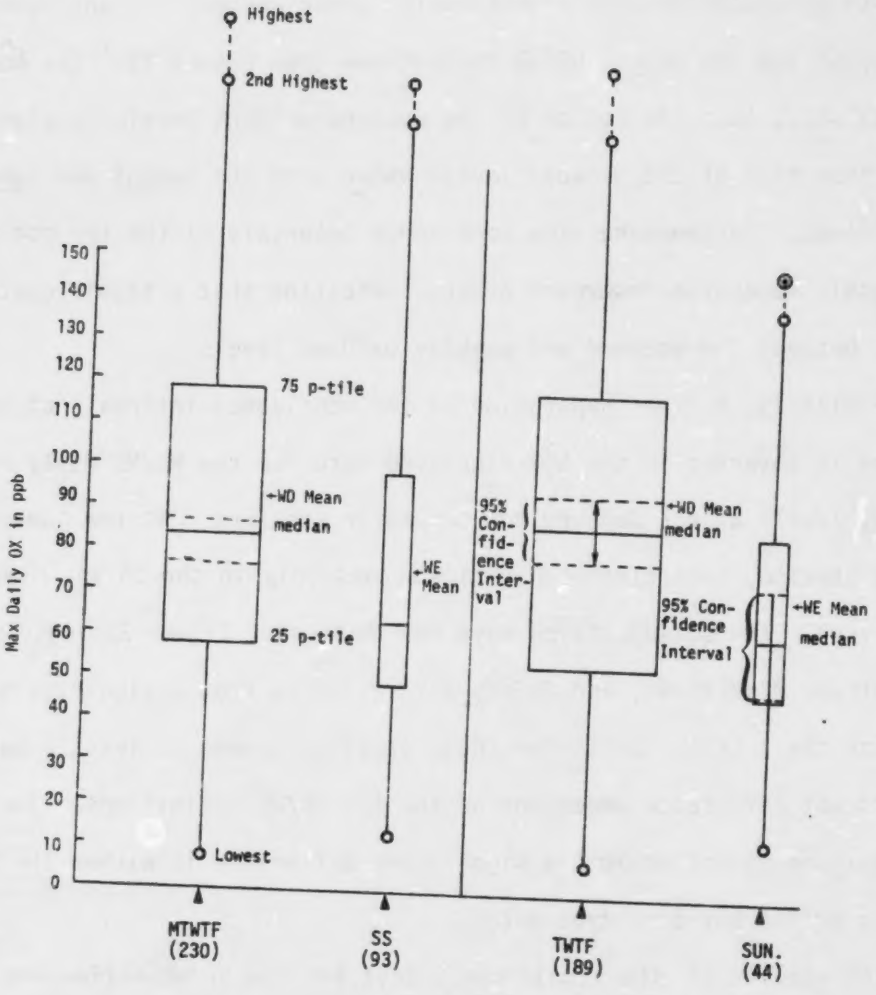


Figure 11. Box-display of WE/WD daily maximum concentrations--under normal and Sunday definitions--for the Greenwich, Connecticut, site.

TABLE 3. SIGNIFICANCE OF THE WE/WD DIFFERENCE IN DAILY MAX OX LEVEL AT EACH STATION BY T-TEST AND OVERALL JUDGMENT

Metropolitan Area	Station Name	SS vs. MTWTF		Sun. vs. TWTF	
		t-Test	Overall	t-Test	Overall
Washington, D.C.	Bethesda (BE)	0	0	θ	0
	Gaithersburg (GA)	0	0	0	0
	Silver Spring (SS)	θ	0	0	0
	Suitland (SU)	θ	0	0	0
Baltimore	Baltimore (BA)	0	0	0	0
	Lancaster (LA)	-	-	θ	-
Philadelphia	Camden (CA)	0	0	0	0
	Camden Co. (CC)	-	-	0	0
	Norristown (NO)	θ	0	0	0
	Philadelphia (PH)	0	0	0	0
New York - Newark	Asbury Park (AP)	0	0	0	0
	Babylon (BB)	0	0	0	0
	Danbury (DA)	-	-	-	-
	Greenwich (GR)	-	-	-	-
	Middletown (MI)	θ	0	0	0
	Mamaroneck (MA)	θ	0	0	0
	Newark (NE)	**θ**	0	0	0
	Welfare Is. (WI)	0	0	0	0
Boston	Medford (ME)	0	0	0	0
	Quincy (QU)	0	0	-	0
	Salem (SA)	0	0	0	0
	Worchester (WO)	0	0	0	0

Note

+	:	WE level is significantly higher than WD level
-	:	WE level is significantly lower than WD level
0	:	WE and WD levels have no significant difference
θ, θ	:	WE/WD differences are marginally significant

insignificant. The overall judgment on the WE/WD difference is also made by considering the consistency of test results by the two different tests employed. Because the overall judgment involves a subjective judgment (particularly in the case of the box-display results), the overall test results are categorized by two levels only: significant and insignificant.

The overall test results are as follows:

- Under the normal WE/WD definition (SS versus MTWTF), four stations exhibit a significant WE/WD difference in daily maximum oxidant levels; the other 18 stations do not exhibit a significant WE/WD difference. All four stations, Lancaster, Camden County, Danbury, and Greenwich, have a significantly lower oxidant level on weekends.
- Under the Sunday WE/WD definition (Sun. versus TWTF), only three stations exhibit a significant WE/WD difference in daily maximum oxidant levels. All three stations, Lancaster, Danbury, and Greenwich, exhibit a significantly lower oxidant level on weekends.

In the next section, WE/WD differences in oxidant levels are examined further, taking into account the effect of meteorology.

4. METEOROLOGICAL ADJUSTMENT OF WE/WD OXIDANT LEVELS

In the preceding sections, we have analyzed weekend/weekday (WE/WD) differences in oxidant concentrations, using all hourly data during the May 1 through September 30 period in four years, 1973 through 1976. Given the long period of air quality data, the results of such an analysis should have only a minimal meteorological bias occurring between weekdays and weekends [Peterson and Flowers 1977; Cleveland et al. 1974a]. Nevertheless, there exists a possibility that a meteorological bias occurring between weekdays and weekends may have affected the WE/WD oxidant differences examined in the preceding sections.

In Section 4.1, seven meteorological variables usually correlated with high oxidant levels are examined for WE/WD differences in order to detect a potential bias on either weekends or weekdays. The impact that any meteorological differences might have on oxidant WE/WD differences are assessed. In Section 4.2, WE/WD oxidant concentrations occurring under similar meteorological conditions are compared. Here, stratifying the oxidant data by meteorological class allows examination of the WE/WD differences on only those days with high oxidant potential. It is under these conditions that reductions in HC and NO_x levels are likely to be most important. This procedure also removes any masking effect that might occur by including days with meteorological conditions that are not conducive to ozone formation. In Section 4.3, the meteorological classes are used to normalize oxidant levels for meteorology, and these results are compared to WE/WD differences using the other schemes. Finally, each site is categorized according to the oxidant WE/WD differences observed under the various analysis techniques.

4.1 WE/WD DIFFERENCES IN METEOROLOGY

The WE/WD difference in meteorology is examined for each of the 12 surface weather stations whose names and site codes are listed in Table 2. The WE/WD differences in each of seven meteorological variables are computed for each surface weather station. Because it is more pertinent to find the WE/WD difference on sampling days with oxidant data rather than on all days, each of the 12 meteorological stations is paired to one of the nearby air monitoring stations. The paired air monitoring station and the number of sampling days at that station are listed in Table 4. The number of sampling days is given separately for weekends and for weekdays.

Table 5 lists the WE/WD levels and the significance level of the WE/WD difference in each of seven meteorological variables. Surprisingly, WE/WD differences are found in nearly all the meteorological variables examined. Some variables show a significant WE/WD difference at several sites, while other variables show a consistent WE/WD difference (in values) among all the sites examined.

The daytime average visibility is consistently better on weekends at all 12 sites examined. At LaGuardia, JFK, Newark, and Philadelphia, the WE/WD differences in visibility are statistically significant. Two other sites, Washington, D.C., and Baltimore, Maryland, exhibit a marginally significant difference. This consistently better visibility on weekends may be due to a decrease in visibility-reducing pollutants on weekends [Peterson and Flowers 1977].

The surface pressure is consistently lower on weekends than on weekdays at all 12 sites. Four sites--Windsor Locks, Connecticut; Bridgeport,

TABLE 4. METEOROLOGICAL STATION AND CORRESPONDING AIR MONITORING STATION USED IN WE/WD METEOROLOGY ANALYSIS

Meteorological Station	Air Monitoring Station	#Valid Cases WE/WD*
Boston, Mass.	Medford, Mass.	148/368
Worchester, Mass.	Worchester, Mass.	129/314
Windsor Locks, Conn.	Middletown, Conn.	99/244
Bridgeport, Conn.	Greenwich, Conn.	114/283
LaGuardia, N.Y.	Welfare Is., N.Y.	126/305
JFK, New York	Babylon, N.Y.	88/211
Newark, N.J.	Newark, N.J.	88/214
Atlantic City, N.J.	Asbury Park, N.J.	92/234
Philadelphia, Pa.	Camden, N.J.	108/278
Washington, D.C.	Suitland, Md.	113/301
Baltimore, Md.	Baltimore, Md.	80/219
Harrisburg, Pa.	Lancaster, Pa.	84/195

*The number of normal weekend days and weekdays with adequate oxidant air quality data.

TABLE 5. T-TEST RESULTS FOR TESTING THE WE/WD DIFFERENCES IN EACH OF SEVEN METEOROLOGICAL VARIABLES

Surface Weather Station	Max Temp, °F WE/WD	Diff.	Avg. Temp, °F WE/WD	Diff.	Avg. Visibility, mi WE/WD	Diff.	Avg. Wind Speed, kn WE/WD	Diff.	Mixing Height, m WE/WD	Diff.	Wind Thru M.L., m/s WE/WD	Diff.	Avg. Pressure, mb WE/WD	Diff.
Boston, Mass.	73.7/74.2	0	65.7/66.5	0	11.2/10.7	0	8.3/8.5	0	1044.3/998.6	0	6.1/6.1	0	1015.6/1016.2	0
Worchester, Mass.	73.7/74.0	0	65.7/66.2	0	11.4/10.9	0	8.7/9.1	-	1088.5/1059.6	0	6.1/6.2	0	1015.4/1016.2	θ
Windsor Locks, Conn.	75.2/75.8	0	68.0/68.9	0	10.5/10.2	0	8.5/8.2	0	1112.3/1067.7	0	5.0/5.9	0	1015.6/1016.8	-
Bridgeport, Conn.	75.2/75.5	0	68.3/68.5	0	10.7/10.6	0	8.7/8.4	0	1069.8/1069.8	0	6.1/6.0	0	1015.9/1017.2	-
La Guardia, N.Y.	75.6/76.4	0	68.7/69.5	0	9.9/9.0	+	8.0/8.0	0	1056.4/1018.5	0	6.1/6.0	0	1015.8/1016.7	θ
JFK, N.Y.	74.2/75.2	0	67.4/68.0	0	11.1/9.6	+	9.1/9.1	0	1040.1/1099.2	0	6.1/6.2	0	1016.1/1017.0	θ
Newark, N.J.	78.1/78.7	0	70.7/71.4	0	11.3/9.6	+	7.4/7.2	0	1123.2/1038.7	0	6.2/6.1	0	1015.3/1016.1	0
Atlantic City, N.J.	77.3/78.4	0	68.6/69.2	0	7.7/7.4	0	7.6/7.3	0	1064.0/1029.0	0	6.0/6.0	0	1016.3/1017.3	θ
Philadelphia, Pa.	78.6/79.9	θ	70.4/71.1	0	10.5/9.0	+	7.5/7.3	0	1303.6/1363.4	0	5.0/5.1	0	1015.7/1016.7	-
Washington, D.C.	81.6/82.0	0	73.3/73.7	0	11.2/10.4	●	6.4/6.6	0	1295.6/1389.3	θ	5.1/5.1	0	1015.9/1017.1	-
Baltimore, Md.	78.0/79.7	θ	69.6/70.6	0	10.0/9.0	●	6.2/6.2	0	1228.2/1382.2	-	5.1/5.0	0	1016.3/1017.1	0
Harrisburg, Pa.	77.7/79.0	0	69.0/69.7	0	9.0/8.3	0	5.2/4.8	●	1489.5/1381.5	0	6.5/6.0	●	1016.5/1017.3	0

- : WE level is significantly lower than WD level
+ : WE level is significantly higher than WD level
0 : WE/WD difference is not significant
θ,● : WE/WD difference is marginally significant

Connecticut; Philadelphia, Pennsylvania; and Washington, D.C.--exhibit a significantly lower pressure level on weekends. Marginally significant weekend drops in surface pressure are found at four additional sites: Worchester, Massachusetts; LaGuardia, New York; JFK, New York; and Newark, New Jersey. These consistent pressure decreases on weekends are rather difficult to explain. A more detailed study of the WE/WD meteorological difference appears to be needed.

A consistently lower weekend level is found in both the daily maximum temperature and the daily average temperature at all the 12 sites. A marginally significant difference in daily max temperature is found at the Philadelphia and Baltimore sites. The WE/WD differences in daily max temperature are not significant at the rest of the 12 sites. The WE/WD differences in daily average temperature are found to be not statistically significant at all the sites. However, because of the consistent bias and because of the known high correlation with daily maximum oxidant levels [Breiman and Meisel 1976], the temperature bias between weekends and weekdays may have affected the WE/WD differences in daily maximum oxidant levels, discussed in the preceding section (Section 3).

The daily average wind speed, afternoon mixing height, and mean wind through the mixing layer also exhibit some difference between weekends and weekdays. However, the WE/WD differences are not consistent and change randomly among the 12 sites. Therefore, we do not expect any significant underlying cause for the WE/WD differences in these meteorological variables.

Although several WE/WD differences are found in the meteorological variables examined, we cannot make any quantitative estimate of the impact of such meteorological biases on the WE/WD oxidant levels. Instead of making a quantitative estimate, we discuss, in the following subsections, a method of removing meteorological biases by comparing the WE/WD oxidant levels under similar meteorological conditions.

4.2 WE/WD DIFFERENCE IN OX WITHIN METEOROLOGICAL CLASSES

In this subsection, meteorological classes for daily oxidant potential are developed for each of the 22 study sites. Then, WE/WD oxidant levels are compared within the same meteorological class. The purpose of meteorological classification is to determine a common meteorological condition under which WE/WD oxidant levels can be compared without a confounding effect of different meteorological conditions. A difference in WE/WD oxidant levels in the same meteorological class is then relatable to differences in WE/WD precursor emissions.

While the effect of meteorology upon air pollution, in particular, oxidant air pollution, has long been recognized, very little has been written concerning actual methods of removing that effect from observed oxidant levels. One method is to develop meteorological classes for a similar daily oxidant potential and to compare WE/WD oxidant levels within the same meteorological class. By noting that meteorological classification is a kind of meteorological pattern recognition, we applied a pattern recognition algorithm called AID (Automatic Interaction Detector, developed at Survey Research Center, University of Michigan, some years ago [Sonquist et al. 1973]) to develop meteorological classes for daily oxidant potential at each study site.

Because meteorological classification should be independent of emissions, we used only weekday data of oxidant and meteorology as inputs to AID. Three meteorological classes, high, middle, and low, are then formed by grouping several original classes produced by the AID program into the high, middle, and low ranges of oxidant concentrations.

4.2.1 AID Decision Tree Analysis

After some unsuccessful attempts at using scatterplot approaches, we have chosen to use the AID computer program to develop meteorological classes for daily oxidant potential. The AID program [Sonquist et al. 1973] simulates the procedures of a good researcher in searching for predictors (meteorological variables) that best account for the variations of a dependent variable (daily maximum oxidant concentration). AID searches over all independent variables for the best split that separates the original data set into the two most uniform subsets. AID keeps dividing each subset until no statistically significant split can be made (see Appendix D). The result is a binary decision (classification) tree that shows graphically the dependence of daily maximum oxidant (OX) levels on the meteorological variables and their ranges.

The AID program is applied to only the weekday data of oxidant and meteorology collected for each of the 22 locations in the northeast United States. The data for the analysis covers the warmer seasons in four years (May through September, 1973 through 1976). The reader is referred to Section 2 (e.g., Figure 2 and Table 2) for a description of the 22 OX monitoring sites and their pairings with surface and upper-air weather sites. The data base for each of the 22 locations includes daily maximum oxidant concentrations and the corresponding values of the eight meteorological variables listed in Table 6. The meteorological data were extracted or computed from weather data obtained from the National Climatic Center (NCC) for 12 surface monitoring sites and 3 upper-air monitoring sites. Of the eight meteorological variables used, the first six variables (T_{max}, TA, P, Vis, WD, and WS) were obtained from surface weather tapes (NCC-TDF 14); the last two variables (MH and $\overline{V}$) were obtained from mixing-height tapes.

Because AID requires the independent variables to be in discrete form, the actual values of the meteorological variables are converted into a discrete class by setting a proper interval of values for each variable. Table 6 lists the intervals used for the meteorological variables. The intervals are determined such that an approximately equal number of data points fall into each interval.

Because we would like to obtain meteorological classes that are independent of emissions, AID is applied to the weekday data only. By excluding all the weekend days from the data base, we can isolate the relationship between daily maximum oxidant level and meteorology from the WE/WD differences in precursor emissions. Given meteorological

TABLE 6. LIST OF METEOROLOGICAL VARIABLES USED FOR SITE-SPECIFIC METEOROLOGICAL CLASSIFICATION OF DAILY MAXIMUM OXIDANT CONCENTRATION BY AID

Variable Name	Symbol	Unit	Ranges Used to Place the Variable into a Discrete Class								
			1*	2	3	4	5	6	7	8	9
Daily Maximum Temperature	T_{max}	°F	[-∞,55)	[55,65)	[65,70)	[70,75)	[75,80)	[80,85)	[85,90)	[90,95)	[95,∞]
Daily Average Temperature	TA	°F	[-∞,50)	[50,55)	[55,60)	[60,65)	[65,70)	[70,75)	[75,80)	[80,85)	[85,∞]
Daily Average Sea-Level Pressure	P	mb	[0,1000)	[1000,1004)	[1004,1008)	[1008,1012)	[1012,1016)	[1016,1020)	[1020,1024)	[1024,1028)	[1028,∞]
Daytime (6 A.M.-9 P.M.) Average Visibility	Vis	mi	[0,2)	[2,4)	[4,6)	[6,8)	[8,10)	[10,12)	[12,16)	[16,20)	[20,∞]
Vector Average Wind Direction	WD	deg	[-45,0)	[0,45)	[45,90)	[90,135)	[135,180)	[180,210)	[210,240)	[240,270)	[270,315)
Daily Average Wind Speed	WS	kn	[0,2)	[2,4)	[4,6)	[6,7)	[7,8)	[8,10)	[10,12)	[12,14)	[14,∞]
Afternoon Mixing Height	MH	m	[0,250)	[250,500)	[500,700)	[700,1000)	[1000,1250)	[1250,1500)	[1500,2000)	[2000,2500)	[2500,∞]
Mean Wind Speed through Mixing Layer	$\bar{V}$	m/sec	[0,2)	[2,3)	[3,4)	[4,5)	[5,6)	[6,7)	[7,8)	[8,12)	[12,∞]

*[-- implies endpoint is included in the range.

(-- implies endpoint is excluded.

classes that are independent of emissions, we will be able to compare the WE/WD oxidant levels under similar meteorological conditions.

Examples of AID decision trees are given in Figures 12, 13, and 14. Figure 12 shows a binary decision tree for the Newark, New Jersey, station, which is the most source-intensive station among the 22 stations analyzed. The decision tree indicates that the highest oxidant air pollution occurs on days with daily maximum temperature (T_{max}) $\geq$ 85°F, daytime average visibility (Vis) < 8 mi, and mean wind speed through mixing layer $2.0 \leq \bar{V} < 6.0$ m/sec. In other words, the highest oxidant pollution days are characterized by high temperature, low visibility, and low wind speeds throughout the mixing layer. Such high-pollution days with mean daily OX of Y = 98.7 ppb occurred 21 days (N=21) out of the 199 days sampled during the summer-month periods (May through September) of four years, 1973 through 1976. On the other hand, the lowest oxidant air pollution occurred on cool days (T_{max} < 75°F). On those days, the mean level of daily maximum OX concentrations over the 54 sample days was as low as Y = 24.4 ppb.

A similar interpretation can be derived easily for other classes from the binary decision trees of Newark and the other two stations: Mamaroneck, New York, and Salem, Massachusetts. A complete set of binary decision trees for all the 22 air monitoring sites is given in Appendix E. By scanning these decision trees, one may find that the daily maximum temperature, T_{max}, is, by far, the most important of the eight meteorological variables considered for explaining the daily maximum oxidant level. Other meteorological variables that have appeared frequently on the

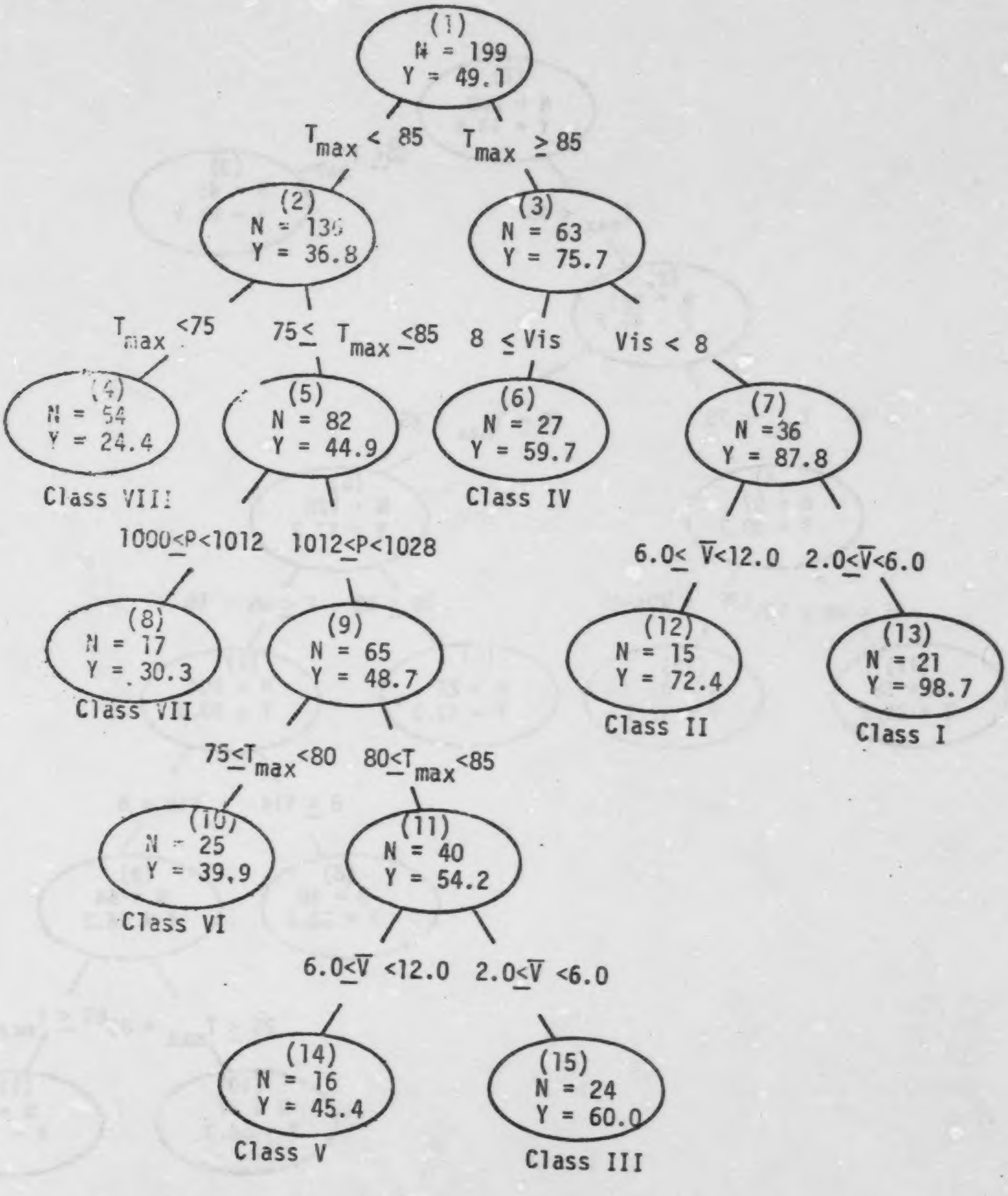

(1)
N = 199
Y = 49.1
$T_{max} < 85$
$T_{max} \geq 85$
(2)
N = 136
Y = 36.8
(3)
N = 63
Y = 75.7
$T_{max} < 75$
$75 \leq T_{max} \leq 85$
$8 \leq Vis$
$Vis < 8$
(4)
N = 54
Y = 24.4
Class VIII
(5)
N = 82
Y = 44.9
(6)
N = 27
Y = 59.7
Class IV
(7)
N = 36
Y = 87.8
$1000 \leq P < 1012$
$1012 \leq P < 1028$
$6.0 \leq \overline{V} < 12.0$
$2.0 \leq \overline{V} < 6.0$
(8)
N = 17
Y = 30.3
Class VII
(9)
N = 65
Y = 48.7
(12)
N = 15
Y = 72.4
Class II
(13)
N = 21
Y = 98.7
Class I
$75 \leq T_{max} < 80$
$80 \leq T_{max} < 85$
(10)
N = 25
Y = 39.9
Class VI
(11)
N = 40
Y = 54.2
$6.0 \leq \overline{V} < 12.0$
$2.0 \leq \overline{V} < 6.0$
(14)
N = 16
Y = 45.4
Class V
(15)
N = 24
Y = 60.0
Class III

Figure 12. Binary decision tree for the Newark, New Jersey, station.

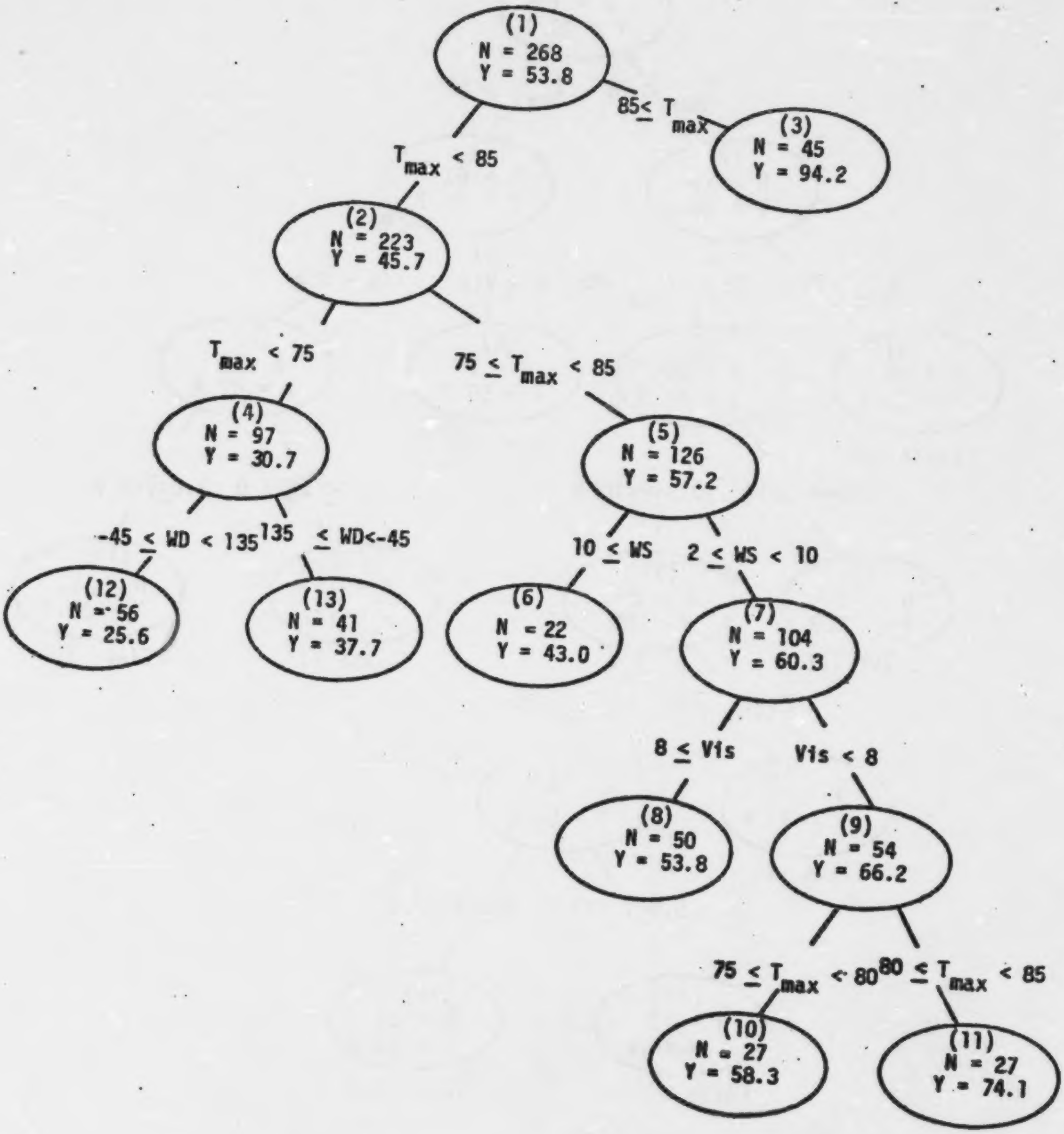

(1)
N = 268
Y = 53.8
85 ≤ Tmax
(3)
N = 45
Y = 94.2
Tmax < 85
(2)
N = 223
Y = 45.7
Tmax < 75
75 ≤ Tmax < 85
(4)
N = 97
Y = 30.7
(5)
N = 126
Y = 57.2
-45 ≤ WD < 135
135 ≤ WD<-45
10 ≤ WS
2 ≤ WS < 10
(12)
N = 56
Y = 25.6
(13)
N = 41
Y = 37.7
(6)
N = 22
Y = 43.0
(7)
N = 104
Y = 60.3
8 ≤ Vis
Vis < 8
(8)
N = 50
Y = 53.8
(9)
N = 54
Y = 66.2
75 ≤ Tmax < 80
80 ≤ Tmax < 85
(10)
N = 27
Y = 58.3
(11)
N = 27
Y = 74.1

Figure 13. Binary decision tree for the Mamaroneck, New York, station.

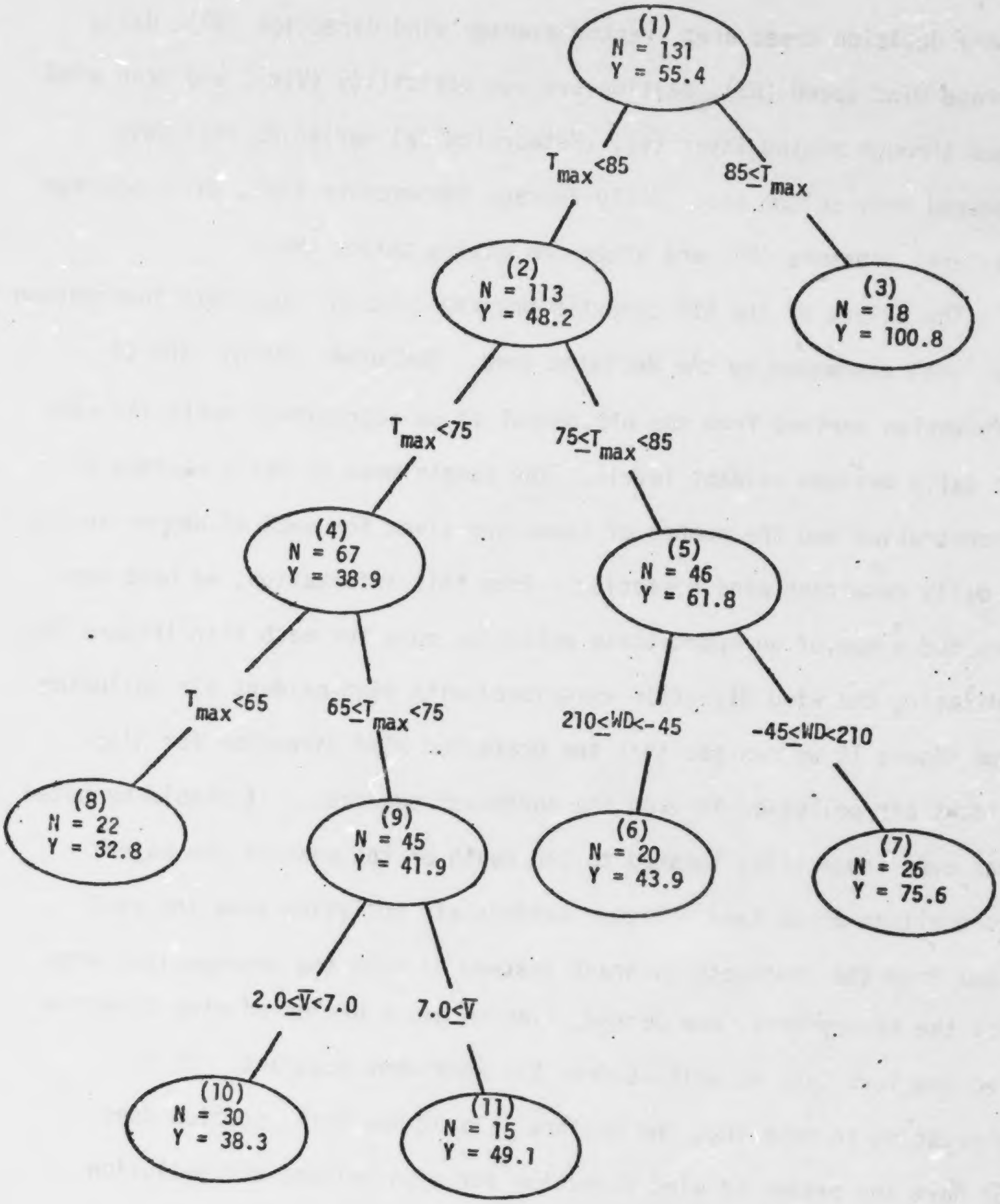

(1)
N = 131
Y = 55.4
$T_{max}<85$
$85\leq T_{max}$
(2)
N = 113
Y = 48.2
(3)
N = 18
Y = 100.8
$T_{max}<75$
$75\leq T_{max}<85$
(4)
N = 67
Y = 38.9
(5)
N = 46
Y = 61.8
$T_{max}<65$
$65\leq T_{max}<75$
$210\leq WD<-45$
$-45\leq WD<210$
(8)
N = 22
Y = 32.8
(9)
N = 45
Y = 41.9
(6)
N = 20
Y = 43.9
(7)
N = 26
Y = 75.6
$2.0\leq \overline{V}<7.0$
$7.0\leq \overline{V}$
(10)
N = 30
Y = 38.3
(11)
N = 15
Y = 49.1

Figure 14. Binary decision tree for the Salem, Massachusetts, station.

binary decision trees are: vector average wind direction (WD), daily average wind speed (WS), daytime average visibility (Vis), and mean wind speed through mixing layer ($\bar{V}$). Meteorological variables that have appeared only seldom are: daily average temperature (TA), daily average sea-level pressure (P), and afternoon mixing height (MH).

The output of the AID computer program contains much more information than that expressed by the decision tree. One other useful kind of information derived from the AID output is an approximate pollution rose for daily maximum oxidant levels. The sample mean of daily maximum OX concentration and the number of cases are given for each 45-degree sector of daily resultant wind direction. From this information, we have constructed a map of an approximate pollution rose for each site (Figure 15), indicating the wind direction associated with high-oxidant air pollution. From Figure 15 we can see that the preferred wind direction for high-oxidant air pollution is from the southwest quadrant. It should be noted that even those sites located to the south or the west of the major metropolitan areas have a higher oxidant air pollution when the wind blows from the southwest quadrant instead of from the metropolitan area. Only the Asbury Park, New Jersey, station has a preferred wind direction from New York City as well as from the southwest quadrant. It is interesting to note that the Welfare Island, New York, station does not have any preferred wind direction for high-oxidant air pollution.

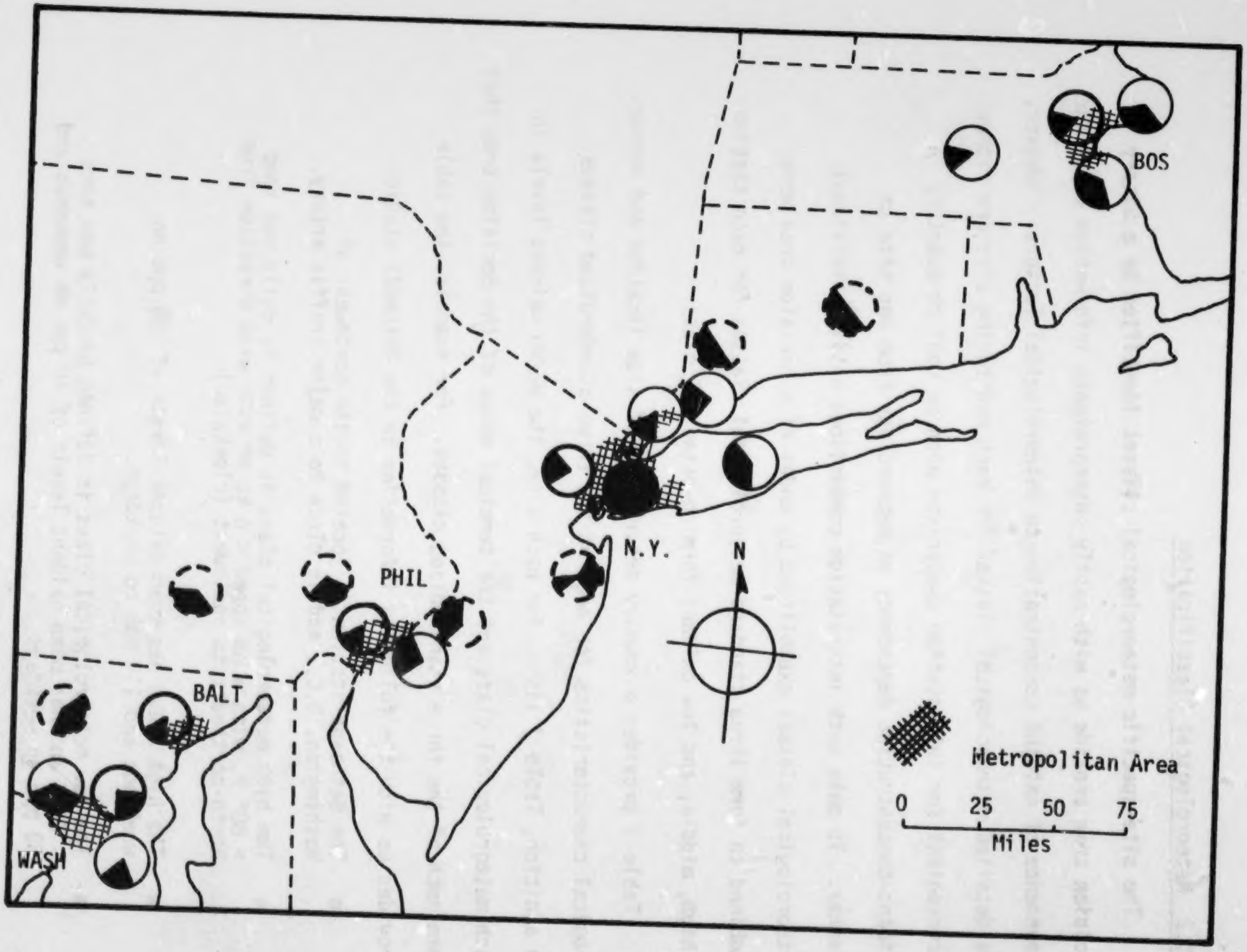

BOS
N.Y.
PHIL
BALT
WASH
N
Metropolitan Area
0
25
50
75
Miles

Figure 15. Preferred wind direction for high-oxidant air pollution at each of the 22 sites.

4.2.2 Meteorological Classification

The site-specific meteorological classes identified by a binary decision tree provide us with easily interpretable information about the dependence of oxidant concentration on meteorological factors. However, the detailed meteorological classes for each monitoring site are rather inconvenient for interstation comparison when we want to quantify oxidant-concentration dependency on meteorology from one site to another. To make such interstation comparisons easily, individual meteorological classes exemplified by nodes of a decision tree were combined to form three standard meteorological classes for each station: a high, middle, and low oxidant-forming-potential class.

Table 7 provides a summary description of site location and meteorological characteristics for each of the three standardized classes. In addition, Table 7 lists, for each site, the WE/WD oxidant levels in each meteorological class and the terminal nodes of the decision tree that form each of the three standardized classes. For example, the table provides us with the following information on the Bethesda station:

- The Bethesda station is located to the northwest of Washington, D.C., and is close to a major traffic artery.
- The high meteorological class is defined by daily max temp > 80° F, with wind speed < 6 kt or with wind direction from North-northeast to southwest (clockwise).
- The high class has mean oxidant levels of 105 ppb on weekends and 114 ppb on weekdays.
- The low meteorological class is defined by daily max temp < 80°F and has mean oxidant levels of 40 ppb on weekends and 50 ppb on weekdays.

TABLE 7. QUALITATIVE DESCRIPTION OF METEOROLOGICAL CHARACTERISTICS FOR HIGH, MIDDLE, AND LOW CLASSES AT EACH OXIDANT MONITORING SITE

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc. (ppb)	Qualitative Description of Meteorology
Bethesda, Md. (BE) 210200005 F01	The Bethesda monitoring site is located to the northwest of Washington, D.C., in a trailer and in an open field. Located at the National Institute of Health close to Wisconsin Ave., a major traffic artery leading into Metro-Wash., D.C. The area is suburban and subject to rush-hour emissions.	High 7,13	WE=105 WD=114	Max temps ≥80°F, avg visibility <8 miles and avg surface wind speed <6 knots, or max temp ≥80°F, avg visibility ≥8 miles and avg wind direction from north-northeast to southwest (clockwise)
		Middle 6,8,12	WE=69 WD=76	Max temp ≥80°F and avg visibility <8 and avg surface wind speed ≥6 knots, or max temp ≥80°F and avg visibility ≥8 miles and wind from the southwest to the northeast (clockwise)
		Low 10,11	WE=40 WD=50	Max temp <80°F
Gaithersburg, Md. (GA) 210780004 G01	The monitoring site is located at the environment lab on Fredrick St. The building is recessed from the street with the monitor placed 35 ft above ground. Major emissions come from traffic.	High 5	WE=81 WD=81	Max temp ≥85°F and avg visibility <8 miles
		Middle 4,7	WE=53 WD=62	Max temp ≥85°F and avg visibility >8 miles, or max temp <85°F but ≥80°F
		Low 6	WE=60 WD=51	Max temp <80°F
Silver Spring, Md. (SS) 211480006 F01	The Silver Spring monitoring station is located due north of downtown Washington, D.C. The site is located 50 ft north of interstate 495, in a trailer 12 ft above ground. Emissions are heavily traffic oriented. The immediate area surrounding the site is dominated by a golf course and residential neighborhood with little heavy industry.	High 6,8,9	WE=71 WD=86	Max temp >85°F and avg surface wind speed <8 knots.
		Middle 4,11	WE=52 WD=54	Max temp >85°F and avg surface wind speed ≥8 knots, or max temp <85°F and avg visibility ≥16 miles
		Low 12,13	WE=33 WD=36	Max temp <85°F and avg visibility <16 miles

TABLE 7. CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc. (ppb)	Qualitative Description of Meteorology
Suitland, Md. (SU) 211560001 F01	Site is located at the Suitland Federal Center. Major arteries in the vicinity are Suitland Parkway and Silver Hill Road. The station will probably reflect rush-hour traffic emissions and some industrial emissions. The monitor is elevated 10 ft above ground.	High 10,11, 14,15	WE=107 WD=107	Max temp >85°F and mean velocity through the mixed layer <4.0 m/s or max temp >85°F and the mean velocity > 4.0 m/s and avg. visibility <12 miles
		Middle 8,17,19	WE=73 WD=74	Max temp >85°F and mean velocity through the mixed layer >4.0 m/s and avg visibility ≥12 miles, or max temp <85°F and mixing height ≥750 m and avg surface wind speed <8 mph and either max temp >80°F or max temp <80°F but ≥55°F and avg pressure ≥1020 mb
		Low 6,12,18	WE=47 WD=49	Max temp <85°F and mixing height <750 m, or max temp <85°F and mixing height ≥750 m and avg surface wind speed ≥8 knots, or max temp <85°F with mixing height ≥750 m, surface wind speed <8 mph max temp <80°F and avg pressure <1020 mb.
Baltimore, Md. (BA) 210120018 F01	The Baltimore air monitoring site is located on 22nd St. and Calvert St. The station is located in a parking lot and is subjected to mainly traffic emissions. There is some industry; however, the site is mainly a center-city type.	High 4,8,9	WE=75 WD=88	Max temp ≥ 85°F
		Middle 10,11	WE=59 WD=54	Max temp <85°F but >75°F
		Low 6	WE=35 WD=32	Max temp <75°F

TABLE 7. CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc. (ppb)	Qualitative Description of Meteorology
Lancaster, Pa. (LA) 394660007 F01	Located in a residential area to the northeast of downtown Lancaster. Emissions are mainly traffic oriented and are generally light. Main arteries are Broad St. and Lehigh Street. The monitor is located on Abraham Lincoln Jr. High School on Gofftown Rd.	High 5,7	WE=104 WD=114	Max temp ≥ 80°F with an avg. visibility < 6 miles or with an average visibility ≥ 6 miles and a mean velocity through the mixed layer ≥ 6.0 m/s.
		Middle 6,13	WE=90 WD=94	Max temp ≥ 80°F and an avg. visibility ≥ 6 miles and a mean velocity through the mixed layer < 6.0 m/s, or max temp ≥ 70°F but < 80°F and a mixing height ≥ 1000 m and an avg. visibility < 10 miles.
		Low 8,10,12	WE=57 WD=61	Max temp < 70°F, or max temp ≥ 70°F but<80°F and a mixing height < 1000 m or max temp ≥ 70°F but < 80°F with a mixing height ≥ 1000 m and an avg. visibility ≥ 10 miles.
Camden, N.J. (CA) 310720003 F01	The site is located in a trailer in a residential area. Davis & Copewood Sts. are not subject to heavy traffic emissions. Industrial emissions are located to the northeast and west at about a distance of two miles. There is a significant number of parks and cemeteries in the general vicinity making the site representative.	High 5,12,13	WE=95 WD=103	Max temp ≥ 90°F or max temp ≥ 80°F but < 90°F and an avg. surface wind speed < 6 knots.
		Middle 9,17,19	WE=72 WD=70	Max temp ≥ 80°F but < 90°F and avg. wind speeds ≥ 6 knots and either winds from the southwest to northwest or winds from northwest to southwest (clockwise) with mixing heights ≥ 1250 m, or max temp < 80°F but ≥ 70°F with winds from east to northwest (clockwise) and mixing height ≥ 1000 m.
		Low 10,14, 16,18	WE=49 WD=41	Max temp < 70°F, or max temp ≥ 70°F but < 80°F and avg. wind from northwest to east, or max temp ≥ 70°F but < 80°F, winds from east to northwest and mixing height < 1000 m, or max temp ≥ 80°F but < 90°F with avg. wind speed ≥ 6 knots, winds from the southwest to northwest and a mixing height < 1250 m.

TABLE 7, CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc (ppb)	Qualitative Description of Meteorology
Camden Co., N.J.(CC) 310740001 F01	The site is located on the grounds of the N.J. State Hospital at Ancoria. The surrounding area is mainly agricultural. The oxidant monitor is 45 ft above ground on the main building of the hospital. The site is subject to local traffic emissions from Rt. 30 and is southeast of Camden.	High 5	WE=112 WD=102	Max temp $\geq$ 75°F and avg. surface wind from the southwest to northwest (clockwise).
		Middle 7	WE=68 WD=82	Max temp $\geq$ 75°F and avg. winds from northwest to southwest (clockwise) and an afternoon mixing height $\geq$ 1250 m.
		Low 2,6	WE=50 WD=57	Max temp < 75°F or max temp $\geq$ 75°F and avg. winds from northwest to southwest (clockwise) and afternoon mixing height < 1250 m.
Norristown, Pa. (NO) 396540013 F01	The site is located 10 miles to the northwest of Philadelphia. Placed on Belvoir Rd., the site is subjected to moderate traffic emissions. Minor industrial emissions come from the southwest and Norristown proper while the station is within 1 mile of the Penn. Turnpike. The monitor is placed 12 ft. above ground at the St. Armory in a residential area	High 7,12,13	WE=108 WD=120	Max temp $\geq$ 90°F and avg. wind speed < 8 knots or a max temp $\geq$ 80°F but < 90°F and a velocity through the mixed layer $\geq$ 3.0 m/s.
		Middle 4,8,15	WE=84 WD=89	Max temp $\geq$ 80°F and avg. wind speed $\geq$ 8 knots, or max temp > 80°F, avg. wind speed < 8 knots and a max temp. <90°F with a mean velocity through the mixed layer < 3.0 m/s, or a max temp. < 80°F but > 75°F and winds from east to northwest.
		Low 10,14	WE=65 WD=55	Max temp < 80°F with winds from northwest to east (clockwise), or max temp < 75 and winds from east to northwest (clockwise).

TABLE 7. CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc. (ppb)	Qualitative Description of Meteorology
Philadelphia, Pa. (PH) 397140026 H01	The Broad and Spruce St. monitoring site is located at the corner of a parking site in downtown Philadelphia. Emissions are heavy and traffic oriented. Broad St. is a main artery running north-south. The site is subject to both industrial and vehicular emissions and is considered characteristic of a downtown metropolitan area.	High 3,8,9	WE=93 WD=81	T max ≥ 90°F, or T max ≥ 80°F but < 90°F and with a mixing height ≥ 1500 m.
		Middle 10,11,15	WE=61 WD=51	T max ≥ 80°F but < 90°F and mixing height < 1500 m, or T max ≥ 75°F but < 80°F and a mixing height ≥ 1250 m.
		Low 12,14	WE=38 WD=31	T max < 75°F, or T max > 75°F but < 80°F with a mixing height < 1500 m.
Asbury Park, N.J. (AP) 310060001 F01	Located on Mattison Ave. between Bond and Main Sts--the commercial center of Asbury Park. The site is elevated (second floor) and is subject to mainly traffic emissions and minor local industry. The location of the monitor is within one mile of the Atlantic Ocean.	High 5	WE=82 WD=89	Mixing height ≥ 1250 m with T max ≥ 80°F.
		Middle 4,7	WE=51 WD=56	Mixing height > 1250 m with T max < 80°F, or mixing height < 1250 m and winds from the southwest to northwest (clockwise).
		Low 6	WE=52 WD=46	Mixing height < 1250 m and winds from northwest to southwest (clockwise).
Babylon, N.Y. (BB) 330280002 F01	The site is located in the center of an industrial park. The general area is residential (parks and cemetery) with major traffic emissions from Rt. 110 which is heavily traveled. In addition Interstate 495 is within 1 mile to the north with continuous heavy traffic. The site is downwind of NYC with the Atlantic Ocean 5 miles to the south.	High 4,5	WE=107 WD=101	Max temp. ≥ 80°F.
		Middle 9	WE=60 WD=72	Max temp < 80°F, wind from the southeast to northwest (clockwise) with max temp > 70°F.
		Low 6,8	WE=50 WD=42	Max temp < 80°F and wind direction from southeast to northwest (clockwise) but max temp < 70°F, or max temp < 80°F and wind direction from northwest to southeast (clockwise).

TABLE 7. CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc. (ppb)	Qualitative Description of Meteorology
Danbury, Conn. (DA) 070175123 F01	Located on a college campus in a residential portion of Danbury. Local emissions are light and come from vehicular traffic and local boilers. The site is downwind (40 miles) of central NYC and is considered very representative of the general area.	High 12,13	WE=88 WD=127	Avg. visibility < 8 miles and avg. wind direction from the southeast to southwest (clockwise).
		Middle 4,6,11	WE=79 WD=94	Avg. visibility < 8 miles and avg. wind direction from southwest to southeast (clockwise), or avg. visibility $\geq$ 8 miles with winds from southeast to northwest and max temps $\geq$ 75°F.
		Low 10,14,15	WE=54 WD=51	Avg. visibility $\geq$ 8 miles with winds from the northwest to southeast, or avg. visibility $\geq$ 8 miles and winds from the southeast to northwest with max temps < 75°F.
Greenwich, Conn. (GR) 070330004 F01	The site is located on Bruce Golf Course near the NY-Conn. state line. The site is considered representative of the general area with local emissions being light, coming from King St., Rt. 684 and Westchester County Airport. NYC is approximately 25 mi to the southwest.	High 6,7	WE=102 WD=125	Max temp $\geq$ 75°F and avg. visibility < 8 miles.
		Middle 8,9	WE=83 WD=92	Max temp $\geq$ 75°F and avg. visibility $\geq$ 8 miles.
		Low 10,11	WE=63 WD=64	Max temp < 75°F.
Mamaroneck, N.Y. (MA) 334100002 F01	Located at the exit to the New England Thruway--35 ft above ground and 50 ft from the curb on 5th St. and Madison. The site is subjected to heavy traffic emissions and not necessarily representative of the general area, which is commercial and situated in a residential community.	High 3,11	WE=79 WD=87	T max $\geq$ 85°F, or T max $\geq$ 75°F but < 85°F and avg. wind speed < 10 knot with visibility < 8 miles and max temp < 80°F.
		Middle 6,8,10	WE=43 WD=53	T max $\geq$ 75°F but < 85°F and avg. wind speed $\geq$ 10 knots, or T max $\geq$ 75°F but $\leq$ 85°F and avg. wind speed < 10 knots and avg. visibility > 8 miles or T max $\geq$ 75°F but < 80°F with avg. wind speed < 10 mph and avg. visibility < 8 miles.
		Low 12,13	WE=36 WD=31	Max temp. < 75°F.

TABLE 7. CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc. (ppb)	Qualitative Description of Meteorology
Middletown, Conn. (MI) 070570003 F01	The site is located at the city hall, approximately 20 ft. above ground. The general area emissions are mixed, including both industry and traffic sources. The site is approximately 70 miles to the northeast of NYC, south of Hartford and north of New Haven.	High 6,7	WE=100 WD=124	Avg. wind direction from southeast to northwest with avg. visibility < 8 miles.
		Middle 4	WE=77 WD=78	Avg. wind direction from southeast to northwest and an avg. visibility $\geq$ 8 miles.
		Low 2	WE=46 WD=47	Avg. wind direction from northwest to southeast (clockwise).
Newark, N.J. (NE) 313480002 F01	Located in downtown Newark on Washington St. and Branford St. The area has industry but is mainly commercial. The station is subjected to moderate-to-heavy traffic from urban congestion. The monitor is placed 12 ft above the ground.	High 12,13,15	WE=87 WD=77	Max temp $\geq$ 85°F and avg. visibility < 8 miles, or max temp $\geq$ 80°F but < 85°F and avg. pressure $\geq$ 1012 mb, and mean velocity through the mixed layer < 6.0 m/s.
		Middle 6,10,14	WE=63 WD=49	Max temp $\geq$ 85°F and visibilitity $\geq$ 8 miles, or max temp $\geq$ 75°F but < 85°F and pressure > 1012 mb and either max temp < 80°F or if max temp $\geq$ 80°F then having a mean velocity through the mixed layer $\geq$ 6 m/s.
		Low 4,8	WE=33 WD=26	Max temp < 75°F, or max temp $\geq$ 75°F but < 85°F and an avg. pressure < 1012 mb.

TABLE 7. CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc (ppb)	Qualitative Description of Meteorology
Welfare Is., N.Y. (WI) 334680050 F01	The site is located at ground level on the north end of the island. The island lies between midtown Manhattan and Queens with the East River Drive along the Manhattan shore. Traffic on the island was limited for the study period; however, the site is downwind of heavy-industrial, power-plant and traffic emissions. The site is well ventilated and probably gives a good representation of East River oxidant.	High 11,14,15	WE=93 WD=94	Max temp $\geq$ 85°F, or max temp $\geq$ 75°F but $<$85°F and winds from the north to southwest with a mixing height $>$ $\geq$750 m and avg. visibility $<$ 10 miles.
		Middle 8,10,17	WE=64 WD=63	Max temp $\geq$ 75°F but $<$ 85°F with winds from the northwest to southwest with either a mixing height $<$ 750 m or with a mixing height $>$ 750 m and an avg. visibility $\geq$ 10 miles, or a max temp $<$ 75°F with wind speed $<$ 8 knots and max temps $\geq$ 70°F.
		Low 6,12,16	WE=39 WD=36	Max temp $\geq$ 75°F and $<$ 85°F with winds from the southwest to northwest, or max temp $<$ 75°F and wind speed $<$ 8 knots and a max temp $<$ 70°F, or a max temp $<$ 75°F and an avg. wind speed $\geq$ 8 knots.
Medford, Mass. (ME) 221220003 F01	Located to the northeast of downtown Boston. The station is situated on a grass-covered median strip at the intersection of Rt. 16 and Rt. 128 and is subjected to moderate-to-heavy traffic volumes. The area is basically commercial and industrial. The station is well ventilated and is considered to be a representative neighborhood station.	High 7,10,11	WE=62 WD=69	Max temp $>$ 85°, or max temp $\geq$ 75°F and $<$ 85°F with mean wind in the mixed layer $\geq$ 5.0 m/s.
		Middle 14,15, 16,17	WE=53 WD=47	Max temps $\geq$ 75° but $<$ 85° and mean wind speeds in the mixed layer $<$ 5.0 m/s, or max temp $\geq$ 70°F but $<$ 75°F and surface winds from the east to northwest (clockwise).
		Low 8,12	WE=36 WD=31	Max temp $<$ 70°F, or max temp $<$ 75°F and wind from northwest to east (clockwise).

TABLE 7. CONT'D

SITE/SAROAD No.	Site Description	Class/ Terminal Node #	Avg. Conc. (ppb)	Qualitative Description of Meteorology
Quincy, Mass. (QU) 221880002 F01	Located to the southeast of Boston on Rt. 3A and Washington St. The site is a curbside location subjected to periodically heavy traffic emissions. The site is well ventilated with numerous industrial sources in the area (i.e., General Dynamic Shipyard, Proctor & Gamble and Edison Power). Site experiences moderate-to-heavy summer daytime traffic volume.	High 8,9,14,15	WE=87 WD=89	Max temps ≥ 80°F.
		Middle 11,13	WE=52 WD=54	Max temps < 80°F but ≥ 75°F and avg. visibility < 10 miles, or max temps < 75°F and the avg. surface winds from the east to northwest (clockwise)
		Low 10,12	WE=43 WD=42	Max temp < 80°F but ≥ 75°F and avg. visibility ≥ 10 miles, or max temp < 75°F and avg. surface winds from the northwest to east (clockwise).
Salem, Mass. (SA) 221980001 F01	Located approximately 10 miles northeast of Boston. The area surrounding the site is residential, located on Highland Ave., and it is subject to moderate traffic. Industrial sources consist of local boilers and a power-generating station approximately 2 miles away.	High 3,7	WE=69 WD=86	Max temp ≥ 85°F, or max temp ≥ 75°F and avg. surface winds from northwest to southwest (clockwise).
		Middle 6,11	WE=42 WD=46	Max temp ≥ 75°F but < 85°F and avg. surface wind from southwest to northwest (clockwise), or max temp ≥ 65°F but < 75°F and mean velocity through mixed layer ≥ 7.0 m/s.
		Low 8,10	WE=43 WD=36	Max temp < 65°F or max temp ≥ 65°F but < 75°F and mean velocity through mixed layer < 7.0 m/s.
Worchester, Mass. (WO) 222640012 F01	Located in a commercial district of Worchester, the station is primarily subjected to traffic emissions. The monitor is situated at the corner of New Salem & Washington Sts. in a monitoring trailer.	High 4,5	WE=74 WD=79	Max temps ≥ 80°F.
		Middle 8,9	WE=52 WD=58	Max temps ≥ 70°F but < 80°F.
		Low 6	WE=46 WD=40	Max temps < 70°F.

For the other stations, similar information can be obtained from Table 7.

Because we are particularly interested in knowing the meteorological conditions existing on high-oxidant days, the meteorological characteristics of the high met class depicted from AID decision trees are summarized in Table 8. For example, the high-oxidant days at Newark, New Jersey, are characterized by a high temperature ≥ 85°F with low visibility < 8 mi or by moderate temperature of 80°F to 85°F with low wind speed aloft < 6 m/sec and high pressure ≥1012 mb. Among the 22 sites examined, as many as 20 sites show high temperature as a key meteorological factor for high-oxidant air pollution. Three other important meteorological factors are low visibility, moderate-to-low wind speed, and south-to-southwesterly wind. Surprisingly, mixing heights greater than 750 m are associated with high oxidant levels at three sites. The high mixing height probably does not indicate a necessary condition for high-oxidant air pollution but simply means low mixing heights are not always associated with high oxidant levels.

4.2.3 WE/WD Differences Within High-OX-Potential Class

This section discusses the WE/WD differences in daily maximum oxidant concentrations on high-oxidant-potential days. Here, the high-oxidant-potential days are determined solely by the meteorological conditions existing on those days. Because AID decision trees are developed from weekday data only, we can expect that the meteorological classes derived from the AID decision trees provide a means of sorting each individual day according to the meteorological oxidant formation potential on that day.

TABLE 8. METEOROLOGICAL CHARACTERISTICS OF HIGH-OXIDANT CLASS FOR EACH SITE

Metropolitan Area	Station Name	T_{max} °F	Vis mi	WS kts	$\bar{V}$ m/sec	WD deg.	MH m	P mb
Washington, D.C.	Bethesda (BE)	≥80 ≥80	<8 >8	<6		[-45,210)		
	Gaithersburg (GA)	≥85	<8					
	Silver Spr (SS)	≥85		<8				
	Suitland (SU)	≥85 ≥85	<12		<4 ≥4			
Baltimore	Baltimore (BA)	≥85						
	Lancaster (LA)	≥80	<6 ≥6		≥6			
Philadelphia	Camden (CA)	>90 [80,90)		<6				
	Camden Co.(CC)	≥75				[240,315)		
	Norristown (NO)	>90 [80,90)		<8 <8				
	Philadelphia(PH)	>90 [80,90)			≥3		≥1500	
New York-Newark	Asbury Park(AP)	≥80					≥1250	
	Babylon (BB)	≥80						
	Danbury (DA)		<8			[135,240)		
	Greenwich (GR)	≥75	<8					
	Middletown(MI)		<8			[135,315)		
	Mamaroneck(MA)	>85 [75,85)	<8	<10				
	Newark (NE)	>85 [80,85)	<8		<6			≥1012
	Welfare Is.(WI)	>85 [75,85)	<10			[-45,240)	≥750	
Boston	Medford (ME)	>85 [75,85)			≥5			
	Quincy (QU)	≥80						
	Salem (SA)	>85 [75,85]				[-45,210)		
	Worchester (WO)	≥80						

NOTE:

[-- implies endpoint is included in the range.

) -- implies endpoint is excluded from the range.

In Table 9, the WE/WD differences in daily maximum oxidant levels for all days and for high-oxidant-potential days only are shown for each of the 22 stations. At 14 of the 22 stations, the WE/WD difference is greater on high-oxidant-potential days. However, the percentage difference is significantly different only at a few sites. The average percentage difference is about the same (-7%) between the two cases, while the absolute WE/WD difference is slightly greater on high-oxidant-potential days.

4.3 METEOROLOGICAL ADJUSTMENT OF WE/WD OXIDANT LEVELS

Fluctuations in meteorology cause most of the day-to-day variation of oxidant concentration levels [Breiman and Meisel 1976]. Consequently, it is desirable to account for the meteorological fluctuations by adjusting the air quality data. One meteorological adjustment method is to compare the WE/WD air quality levels under similar meteorological conditions, say, the high met class developed in the preceding subsection. Another meteorological adjustment method would be to compute a frequency weighted average of the means of high, middle, and low classes for weekends and that for weekdays. Zeldin and Meisel [1978] show that meteorological normalization of air quality parameters (such as the arithmetic mean and geometric mean) can be performed if one is able to determine meteorological classes that explain a significant fraction of air quality variance. For example, a meteorologically normalized arithmetic mean can be computed as follows:

TABLE 9. WE/WD DIFFERENCES IN DAILY MAX OX LEVELS FOR ALL CASES AND FOR HIGH MET CLASS ONLY (SS vs. MTWTF)

Metropolitan Area	Station Name	All Cases			High Met. Class		
		WE Level (ppb)	WD Level (ppb)	% Change (WE-WD)	WE Level (ppb)	WD Level (ppb)	% Change (WE-WD)
Washington D.C.	Bethesda	70	77	-9%	105	114	-8%
	Gaithersburg	61	64	-4%	81	81	0%
	Silver Spring	52	59	-13%	71	86	-17%
	Suitland	73	79	-8%	107	107	0%
Baltimore	Baltimore	54	59	-9%	75	88	-15%
	Lancaster	82	91	-8%	104	114	-9%
Philadelphia	Camden	68	70	-2%	95	103	-8%
	Camden Co.	64	75	-14%	112	102	+10%
	Norristown	82	91	-9%	108	120	-10%
	Philadelphia	58	57	+2%	93	81	+15%
Newark - New York	Asbury Park	55	57	-4%	82	89	-8%
	Babylon	66	70	-7%	107	101	+6%
	Danbury	71	87	-18%	88	127	-31%
	Greenwich	79	92	-15%	102	125	-18%
	Mamaroneck	49	54	-8%	79	87	-9%
	Middletown	73	82	-11%	100	124	-19%
	Newark	56	49	+13%	87	77	+13%
	Welfare Is.	62	61	+1%	93	94	-1%
Boston	Medford	50	49	+2%	62	69	-10%
	Quincy	60	62	-4%	87	89	-2%
	Salem	49	55	-12%	69	86	-20%
	Worchester	56	58	-3%	74	79	-6%
	22 Station Avg.*	63	68	-7%	90	97	-7%

*The station-average percentage difference is computed from the station averages of WE/WD concentration levels.

$$\bar{C}_{k,\mathrm{Norm}} = \sum_{i=1}^{M} \bar{C}_{ki} \; P_i \quad , \qquad (2)$$

where $\bar{C}_{k,\mathrm{Norm}}$ = the meteorologically normalized mean for a pollutant (e.g., oxidant) in the k^{th} period (e.g. weekends),

M = the number of meteorological classes,

$\bar{C}_{ki}$ = the sample mean of meteorological class "i" (e.g., high class) during the k^{th} period,

P_i = the average frequency of occurrence of meteorological class "i" during all periods (e.g., all days).

The following paragraphs describe a meteorological adjustment of the actually observed WE/WD difference according to Equation (2). In making such a meteorological adjustment, we utilized the three standardized meteorological classes developed in the preceding subsection. Figure 16 is a bar graph showing the WE/WD mean concentrations in the high-, middle-, and low-oxidant-potential classes at Lancaster, Pennsylvania. The figure also shows the number of cases in each class on weekends and weekdays.

The meteorologically adjusted weekend mean for all cases represented by the figure is given by

$$\bar{C}_{\mathrm{WE,Norm}} = \sum_{i=1}^{3} \bar{C}_{\mathrm{WE},i} \; P_i \ , \qquad (2\text{-a})$$

where i = 1, 2, 3 indicates, respectively, high, middle, and low classes, and $\bar{C}_{WE,i}$ is the mean weekend oxidant level of the i^{th} class. P_i is the average frequency of occurrence of each of the three classes during all days, i.e., weekends and weekdays combined. Similarly, the meteorologically adjusted weekday mean is given by

$$\bar{C}_{WD,Norm} = \sum_{i=1}^{3} \bar{C}_{WD,i} P_i , \qquad (2\text{-}b)$$

where $\bar{C}_{WD,i}$ is the mean weekday OX level of the i^{th} class.

As seen from Figure 16, the Lancaster station exhibits a consistently lower oxidant level on weekends among the class means of each of the three meteorological classes, the actual means, and the meteorologically adjusted means. Because of the consistently lower weekend levels among all the five different WE/WD comparisons, one can say that the weekend OX level is lower at this station. The above consistently lower type of station is termed a "Type I station."

Figure 17 is a bar graph for the Newark, New Jersey, station. This station exhibits a consistently higher weekend OX level among the five different WE/WD comparisons. Therefore, we can expect that the weekend OX level is higher at this station. The above type of station is termed a "Type II station."

Figure 18 snows the bar graph comparisons of the WE/WD oxidant levels at Baltimore, Maryland. Unlike the above two examples, the WE/WD relationship is reversed from one comparison to another. While the weekend OX level is lower in the high class, those in the middle and

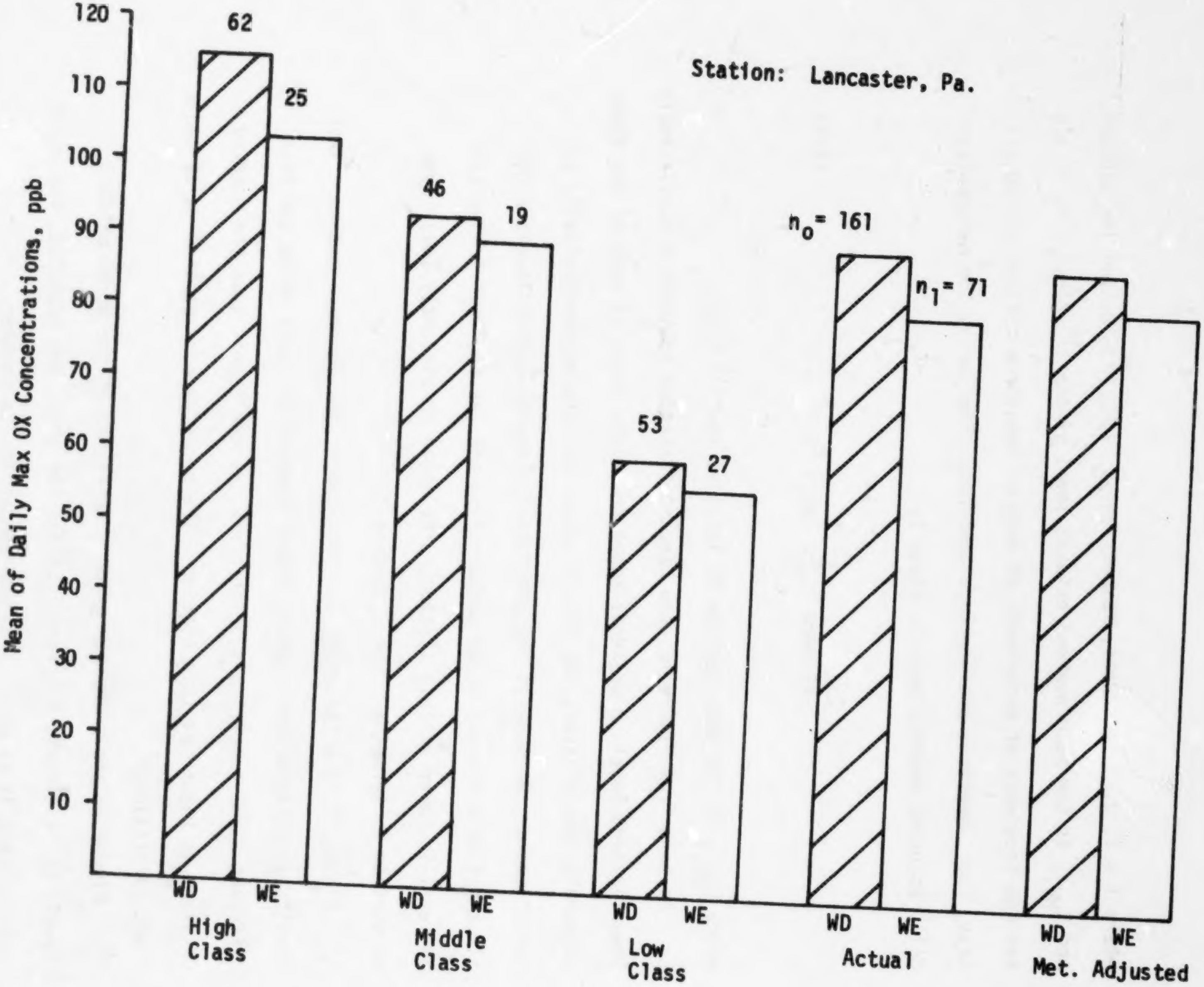


Figure 16. Example of Type I station, which exhibits a consistently lower weekend OX level in every WE/WD comparison.

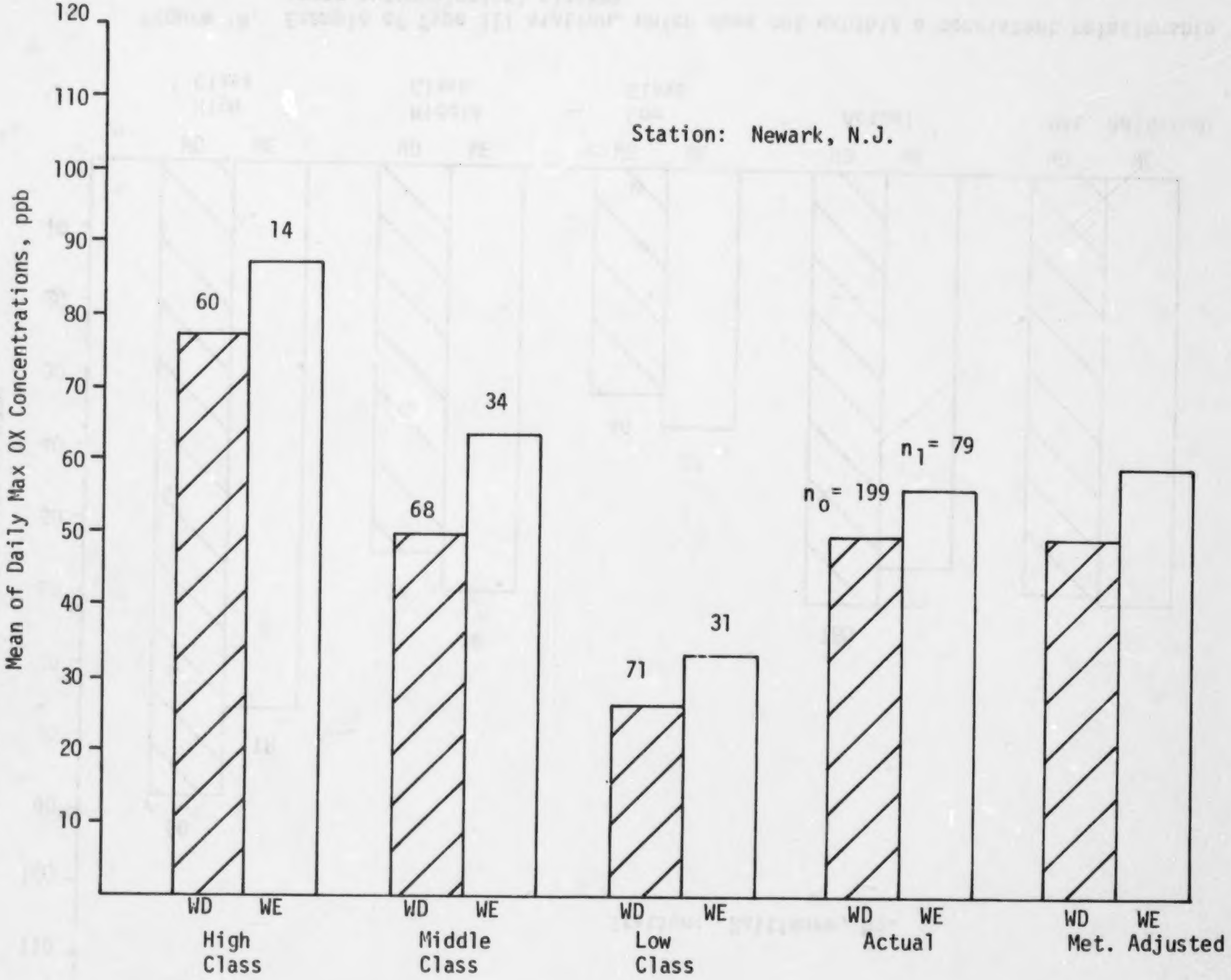


Figure 17. Example of Type II station, which exhibits a consistently higher weekend OX level in every WE/WD comparison.

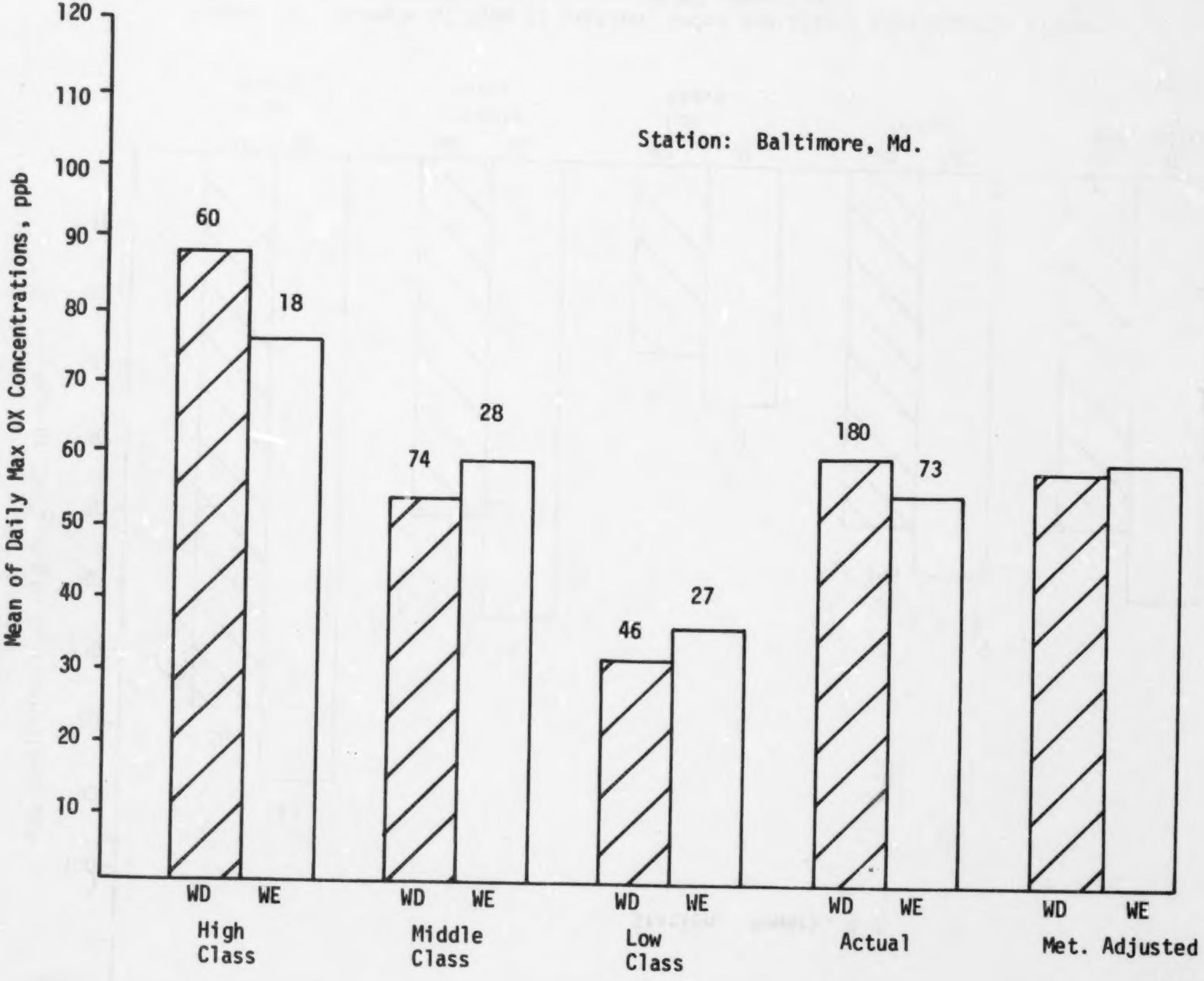


Figure 18. Example of Type III station, which does not exhibit a consistent relationship among meteorological classes

low classes are higher. While the actual WE/WD means show a lower weekend level, the meteorologically adjusted WE/WD means indicate a slightly higher weekend level. The Baltimore station does not show a consistent WE/WD relationship among the five comparisons. Therefore, we cannot say whether the weekend OX level is higher or lower than the weekday level for this station. The above type of station is termed a "Type III station."

In the next section, these classifications are used to categorize the WE/WD differences in oxidant concentrations at each site.

4.4 CLASSIFICATION OF SITES

Table 10 summarizes the results of grouping the 22 oxidant monitoring stations into the above-defined three station types. The table lists six Type I stations that exhibit a consistently lower OX level on weekends, and an additional seven stations having a consistently lower weekend level with one exception. These 13 stations are all located either in the periphery or outside the large metropolitan areas. Table 10b presents the four Type II stations that exhibit a consistently higher OX level on weekends: Philadelphia, Newark, Welfare Island, and Medford. These four stations are all located in the most urban, source-intensive areas.

Table 10c lists the five Type III stations that do not exhibit a consistent relationship among the five different WE/WD comparisons. The reason why, at these stations, the WE/WD oxidant relationship is altered from one class to another is not known. However, one possible explanation could be that these stations classed into Type III have only a weak WE/WD

TABLE 10. CLASSIFICATION OF WE/WD DIFFERENCES

a. Type I stations, which exhibit a consistently lower OX level on weekends.

Station	Sample Size	%WE	High Class % Change (WE-WD)	Middle Class % Change (WE-WD)	Low Class % Change (WE-WD)	Actual % Change (WE-WD)	Met. Adjusted % Change (WE-WD)
Bethesda, Md.	286	31	- 8	- 9	-20	- 9	- 8
Silver Spring, Md.	248	27	-17	- 4	- 8	-13	-12
Greenwich, Conn.	340	29	-18	-12	- 2	-15	-11
Middletown, Conn.	284	29	-19	- 1	- 2	-11	-10
Lancaster, Pa.	232	31	- 9	- 4	- 7	- 8	- 6
Norristown, Pa.	239	31	-10	- 6	-18	- 9	- 3
With One Exception							
Camden Co., N.J.	224	28	+10	-17	-12	-14	- 8
Danbury, Conn.	250	30	-31	-16	+ 6	-18	-17
Mamaroneck, N.Y.	377	29	- 9	-19	+16	- 8	- 6
Quincy, Mass.	458	30	- 2	- 6	+ 1	- 4	- 3
Salem, Mass.	185	29	-23	- 9	+19	-12	- 6
Suitland, Md.	351	29	0	- 1	- 4	- 8	- 1
Worchester, Mass.	350	32	- 6	-10	+15	- 3	- 3

b. Type II stations, which exhibit a consistently higher OX level on weekends.

Newark, N.J.	278	28	+13	+29	+27	+13	+24
Philadelphia, Pa.	293	30	+15	+20	+23	+ 2	+17
With One Exception							
Medford, Mass.	415	30	- 7	+13	+16	+ 2	+ 2
Welfare Is., N.Y.	362	29	- 1	+ 2	+ 8	+ 1	+ 2

c. Type III stations, which do not exhibit a consistent relationship among meteorological classes.

Asbury Park, N.J.	197	28	- 8	- 9	+13	- 4	+ 1
Babylon, N.Y.	238	29	+ 6	-17	+19	- 7	+ 1
Baltimore, Md.	253	29	-15	+ 9	+ 9	- 9	+ 1
Camden, N.J.	371	29	- 8	+ 3	+20	- 2	+ 2
Gaithersburg, Md.	140	32	0	-15	+18	- 4	- 3

difference in daily max OX levels so that the WE/WD oxidant relationship can be altered by sample variation from one meteorological class to another. Those stations classed into Type I and Type II have a strong enough WE/WD difference in daily max OX levels so that the WE/WD oxidant relationship cannot be altered easily by sample variation from one meteorological class to another.

5. DIFFERENCES IN OXIDANT PRECURSOR LEVELS

In Sections 3 and 4, WE/WD differences in daily maximum oxidant levels were examined. This section discusses the WE/WD differences in oxidant precursor levels. The 6-9 A.M. (EDT) average concentrations of nitric oxide (NO), nitrogen dioxide (NO_2), nonmethane hydrocarbons (NMHC), and total hydrocarbons (THC) are examined. The two major oxidant precursors are NO_x and NMHC. NO_x is defined as the sum of NO and NO_2 concentrations. Most NO_x is emitted to the atmosphere in the form of NO and is subsequently oxidized to NO_2. Nonmethane hydrocarbons are defined as the difference between total hydrocarbons (THC) and methane (CH_4).

In addition to the four pollutants, the 6-9 A.M. averages of (NO_2/NO_x) ratios and carbon monoxide (CO) concentrations are also examined. Because NO works as a scavenger of OX while NO_2 works as a promoter of OX, an ambient (NO_2/NO_x) ratio provides an indication of net oxidant formation potential of the atmosphere [Jeffries et al. 1976]. CO is an inert gas that is mainly emitted by automobiles. Because ambient CO levels may very well be an indicator of automotive-related precursor levels, WE/WD differences in those data were also examined.

5.1 DIFFERENCES IN 6-9 A.M. AVERAGE NO AND NO_2 CONCENTRATIONS

Ambient NO and NO_2 data are not as complete as the oxidant data analyzed in Sections 3 and 4. After checking the data completeness at each air monitoring site, we found adequate NO and NO_2 data at the eight stations whose names, site codes, and sample sizes are listed in Table 11. The sample size is given for both the normal (SS vs. MTWTF) and Sunday (Sun vs. TWTF) WE/WD definitions. The eight stations are

TABLE 11. MONITORING STATIONS USED FOR ANALYZING NO AND NO_2 AIR QUALITY DATA

Metropolitan Area	Station Name	SAROAD I.D.	EPA's Site Code*	Number of Valid Observation Days†	
				SS vs. MTWTF	Sun. vs. TWTF
Washington, D.C.	Bethesda	210200005 F01	S-R	115	85
	Silver Spring	211480006 F01	S	121	87
	Suitland	211560001 F01	S	111	82
Baltimore	Baltimore	210120018 F01	CC-C	194	137
Philadelphia	Camden	310720003 F01	S-R	202	149
New York City	Mamaroneck	334100002 F01	CC-C	224	166
	Newark	313480002 F01	CC-C	194	140
	Welfare Is.	334680050 F01	CC	213	151

*Code key:

C - Commercial
CC - Center City
R - Residential
S - Suburban

†A "valid observation day" is a day which has at least 2 out of 3 possible observations during the 6-9 A.M. (EDT) period.

all located within or near one of the large metropolitan areas (see Figure 2).

5.1.1 WE/WD Differences in NO Concentrations

The WE/WD differences in 6-9 A.M. average NO concentration levels are computed for both the normal and Sunday WE/WD definitions. The results are summarized in Table 12. All the stations except for Bethesda exhibit a large drop in 6-9 A.M. average NO levels on weekends. The weekend reductions in 6-9 A.M. average NO levels range from 40% at Mamaroneck, New York, to 83% at Camden, New Jersey, under the normal WE/WD definition. Under the Sunday WE/WD definition, the drop is generally greater than that under the normal definition. Also, the weekend reductions in the eight-station 6-9 A.M. NO levels are 60% and 67% under the normal and Sunday WE/WD definitions, respectively. The Sunday WE/WD definition (Sunday versus Tuesday through Friday), therefore, yields a slightly larger change between the WE/WD 6-9 A.M. average NO levels than the normal WE/WD definition.

The NO behavior at the Bethesda station is different from that at the other stations. In contrast to the large weekend drops at the other stations, the Bethesda station exhibits a large increase in 6-9 A.M. average NO concentrations on weekends. The increases are 134% and 252%, respectively, under the normal and Sunday WE/WD definitions. A close examination of the Bethesda NO data revealed that the weekend NO data contained a few extremely high NO concentrations. The standard deviation of the weekend NO data is much larger than that of the weekday NO data (5.3 pphm versus 1.4 pphm under the normal WE/WD definition and 7.6 pphm versus 1.4 pphm

TABLE 12. WE/WD DIFFERENCES IN 6-9 A.M. AVERAGE NO CONCENTRATIONS

Station Name	SS vs. MTWTF			Sun. vs. TWTF		
	Mean WE level (pphm)	Mean WD level (pphm)	% Change (WE-WD)	Mean WE level (pphm)	Mean WD level (pphm)	% Change (WE-WD)
Bethesda	1.5	0.7	+ 134%	2.3	0.7	+ 252%
Silver Spring	5.3	12.8	- 58%	3.6	13.0	- 72%
Suitland	0.5	1.3	- 60%	0.1	1.4	- 93%
Baltimore	1.0	4.6	- 79%	0.9	4.4	- 80%
Camden	0.9	5.4	- 83%	0.9	5.4	- 84%
Mamaroneck	1.9	3.2	- 40%	1.4	3.4	- 60%
Newark	2.2	6.3	- 65%	1.8	6.6	- 72%
Welfare Is.	1.4	2.4	- 43%	1.3	2.4	- 45%
8-Station Avg.	1.8	4.6	- 60%*	1.5	4.7	- 67%*

*The station-average percentage difference is computed from the station averages of WE/WD concentration levels.

under the Sunday WE/WD definition). Because of this large difference between the WE/WD standard deviations, the results for the Bethesda station should be viewed with caution.

The WE/WD differences in 6-9 A.M. average NO levels are examined by using the t-test. Figure 19 shows the significance level of the WE/WD difference at each station under the normal and Sunday WE/WD definitions. Among the eight stations examined, five--Silver Spring, Baltimore, Camden, Newark, and Mamaroneck--exhibit significant WE/WD differences in 6-9 A.M. average NO levels under both the normal and Sunday WE/WD definitions. The remaining three stations, Bethesda, Suitland, and Welfare Island, show a marginally significant difference under one of the two WE/WD definitions.

The t-test results are also presented in Figure 20, in which the standardized values of Sunday/WD 6-9 A.M. average NO levels are plotted on the x-y axes. The standardized value is a dimensionless number given by a ratio of the mean to the square root of the pooled variance (see Appendix A for definition). Therefore, the standardized values of WE and WD can be compared directly, and their difference is exactly the t-value. Figure 20 clearly shows that the WE NO level is lower than the WD level at all the stations except Bethesda.

5.1.2 WE/WD Differences in NO_2 Concentrations

The WE/WD differences in 6-9 A.M. average NO_2 levels are examined for the same eight stations as were used for the analysis of NO concentrations. The mean WE level, the mean WD level, and the percentage change between weekends and weekdays are listed in Table 13. On the average for the eight stations, the weekend NO_2 level is 42% lower than the weekday

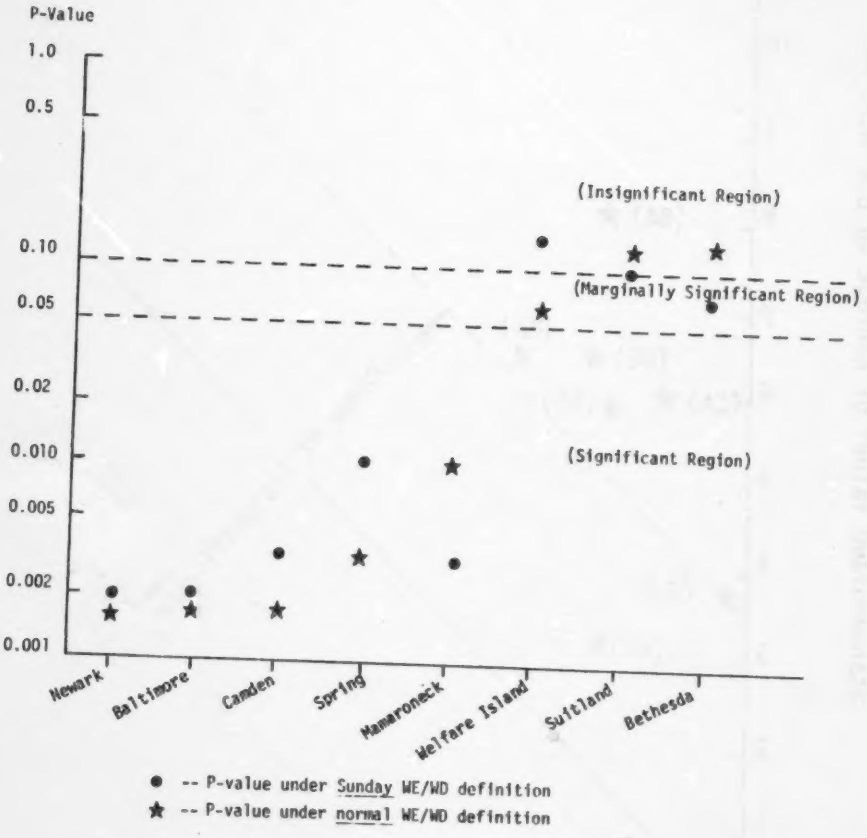
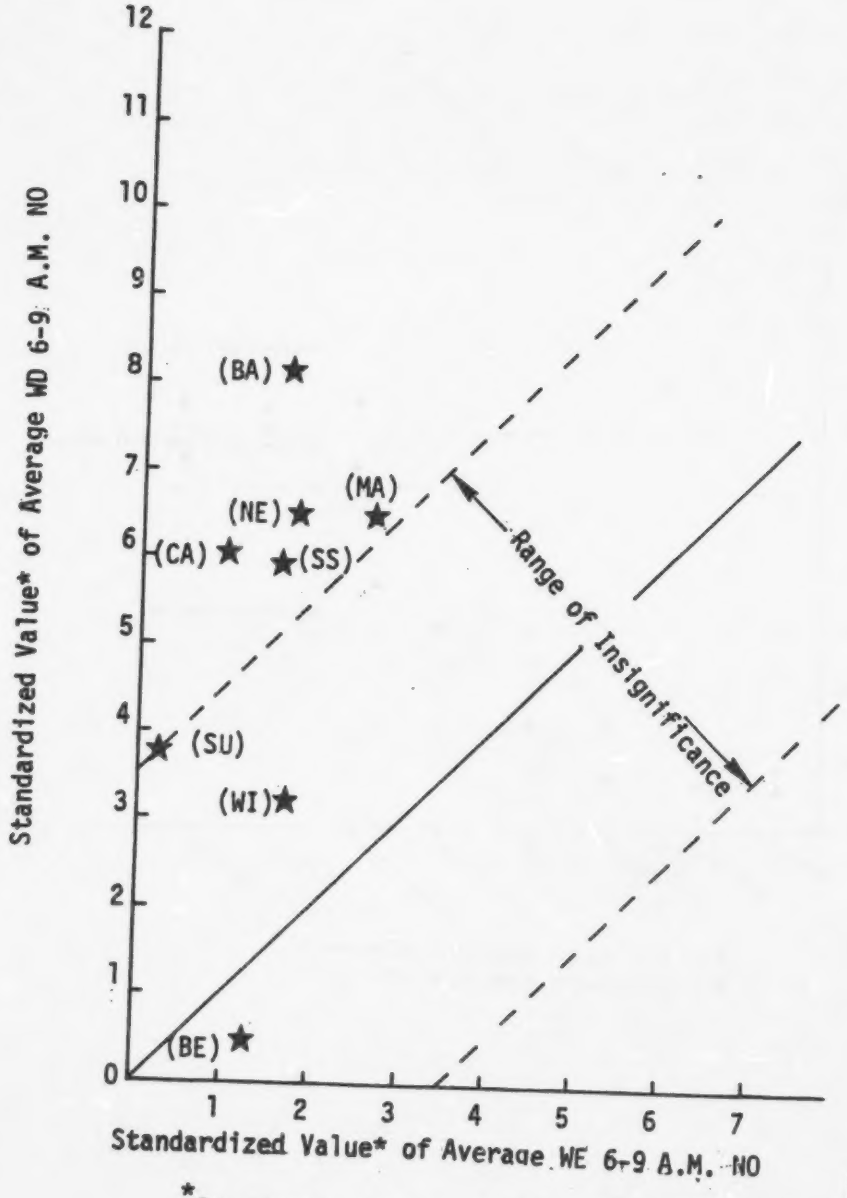


Figure 19. P-values for testing WE/WD differences in 6-9 A.M. average NO by t-test.



*Standardized value = mean/$\sqrt{\text{pooled variance}}$

Figure 20. Graphical presentation of t-test results for WE/WD difference in 6-9 A.M. average NO concentrations (Sun. vs. TWTF).

TABLE 13. WE/WD DIFFERENCES IN 6-9 A.M. AVERAGE NO_2 CONCENTRATIONS

Station Name	SS vs. MTWTF			Sun. vs. TWTF		
	Mean WE level (pphm)	Mean WD level (pphm)	% Change (WE-WD)	Mean WE level (pphm)	Mean WD level (pphm)	% Change (WE-WD)
Bethesda	1.3	3.1	- 59%	1.1	3.0	- 64%
Silver Spring	3.4	5.6	- 39%	3.0	5.6	- 47%
Suitland	3.2	5.7	- 44%	3.0	5.7	- 47%
Baltimore	3.4	6.6	- 48%	3.0	6.7	- 55%
Camden	1.8	3.3	- 47%	1.7	3.3	- 47%
Mamaroneck	1.5	2.0	- 22%	1.2	2.0	- 43%
Newark	2.9	4.0	- 27%	3.0	4.2	- 28%
Welfare Is.	1.8	3.2	- 42%	1.7	3.3	- 48%
8-Station Avg.	2.4	4.2	- 42%*	2.2	4.2	- 48%*

*The station-average percentage difference is computed from the station averages of WE/WD concentration levels.

level, under the normal WE/WD definition; while under the Sunday WE/WD definition, the mean weekend NO_2 level is 48% lower than the weekday level. The percentage drop of 6-9 A.M. average NO_2 levels on weekends is slightly smaller than that of 6-9 A.M. average NO levels under both the normal and Sunday WE/WD definitions.

Unlike the NO case, the NO_2 concentration data for the Bethesda station do not behave strangely. However, the weekend percentage drop of 6-9 A.M. average NO_2 levels is largest at the Bethesda station among the eight stations examined. Under the normal definition, the Mamaroneck station has the smallest percentage drop, 22%, on weekends, while under the Sunday definition, the Newark station exhibits the smallest drop, 28%.

As seen from Figure 21, the t-test results of the WE/WD NO_2 data indicate that, at all eight station sites, the WE/WD differences in 6-9 A.M. average NO_2 levels are significant under both the normal and Sunday WE/WD definitions. The standardized values of WE/WD 6-9 A.M. average NO_2 levels are plotted in Figure 22, showing that all the stations have significantly lower NO_2 levels on weekends than on weekdays.

5.2 WE/WD DIFFERENCES IN NO_2/NO_x RATIOS

The preceding subsection has revealed that both NO and NO_2 concentrations are significantly lower in the 6-9 A.M. period on the weekends than in the same period on weekdays. The remaining question is whether the (NO_2/NO_x) ratio is also significantly different between weekends and

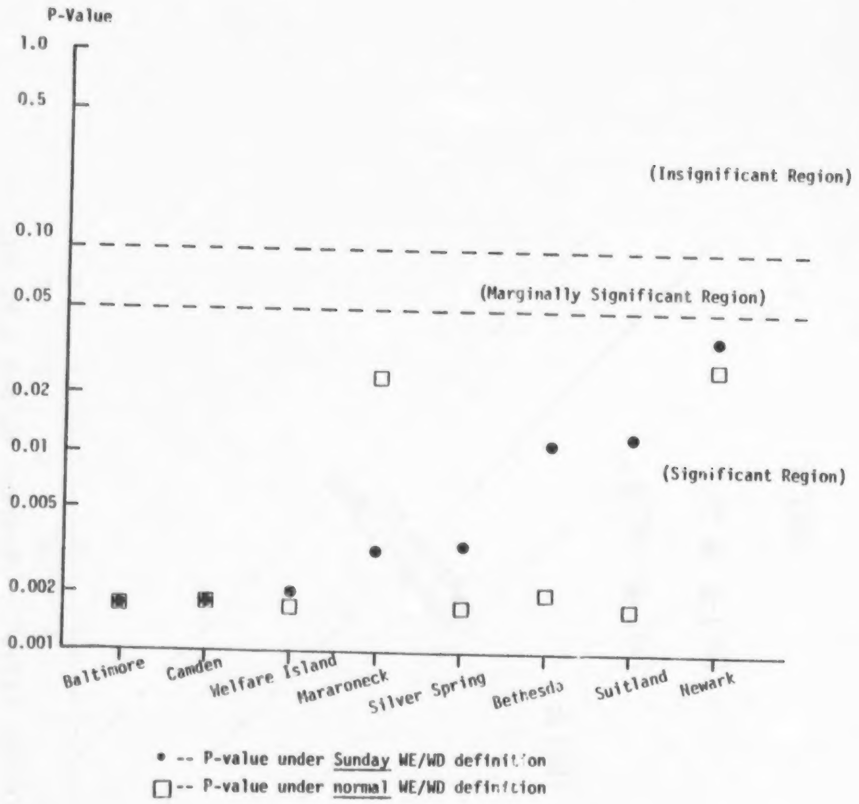
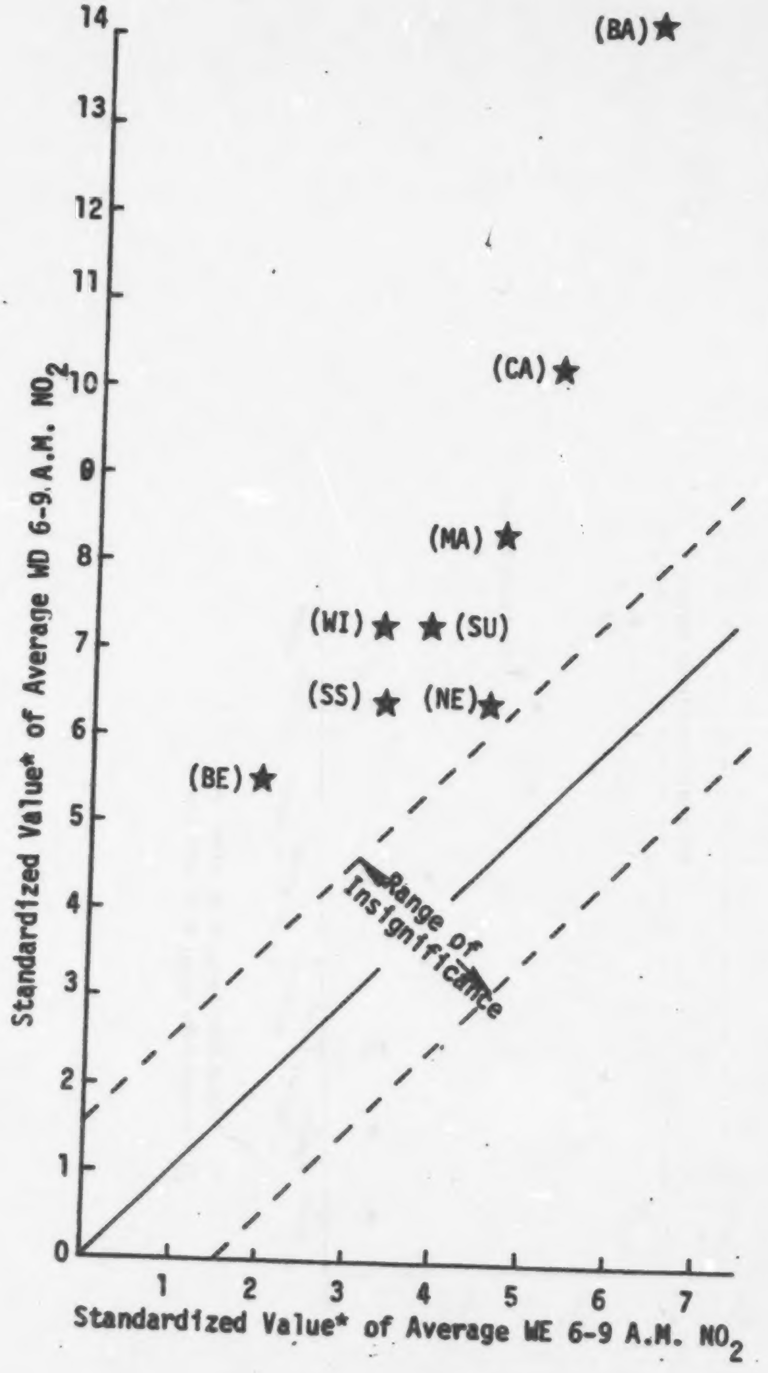


Figure 21. P-values for testing WE/WD difference in 6-9 A.M. average NO_2 by t-test.



*Standardized Value = mean/$\sqrt{\text{pooled variance}}$

Figure 22. Graphical presentation of t-test results for WE/WD difference in 6-9 A.M. average NO concentrations (Sun. vs. TWTF).

weekdays. The important oxidant precursor, NO_x, consists mainly of NO and NO_2. While NO scavenges ambient OX by reductive reactions, NO_2 promotes OX formation by oxidation reactions. Therefore, the (NO_2/NO_x) ratio indicates how ambient NO_x works on ambient OX levels. Because NO_2 is formed by oxidation of NO, the (NO_2/NO_x) ratio also may indicate the age of the ambient NO_x gas mixture. The greater the (NO_2/NO_x) ratio, the older the pollutants measured in the air mass are likely to be. In actual calculation of the ratio, we use $(NO_2 + NO)$ as an approximate level of NO_x.

In testing the WE/WD differences in 6-9 A.M. average (NO_2/NO_x) ratios, we encountered a difficulty: The t-test cannot be used to validate such differences because the distribution of (NO_2/NO_x) is a bounded one, always lying between 0 and 1. Fortunately, the Wilcoxon rank sum test (see Appendix B) is known to be efficient over a wide range of distributions, including a bounded one. We therefore applied the Wilcoxon rank sum test to test observed WE/WD differences in 6-9 A.M. average (NO_2/NO_x) ratios at each of the eight stations.

The P-values of the Wilcoxon rank sum test for the eight stations are plotted in Figure 23. Three stations, Camden, Newark, and Mamaroneck, exhibit a significantly higher (NO_2/NO_x) ratio on weekends, indicating that the 6-9 A.M. weekend NO_x gas mixture is more aged than the weekday NO_x gas mixture at these sites. As in the case of NO concentrations, the Bethesda station exhibits strange behavior in its 6-9 A.M. average (NO_2/NO_x) ratios. Only this station shows that the weekend level of 6-9 A.M. average (NO_2/NO_x) ratios is significantly lower than the weekday level.

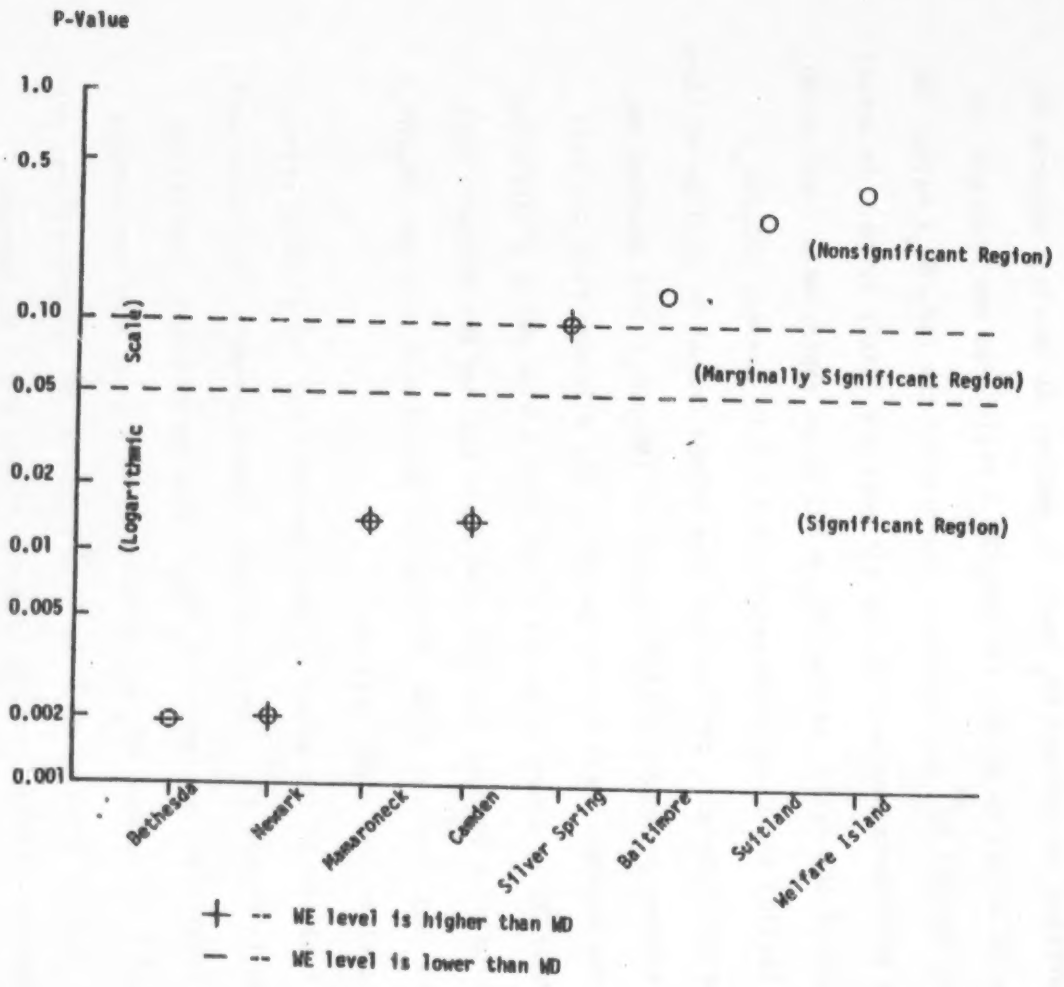


Figure 23. P-values for testing the WE/WD difference in NO_2/NO_x ratio by the Wilcoxon rank sum test (Sun. versus TWTF).

The WE/WD differences in 6-9 A.M. average (NO_2/NO_x) ratios at each of the eight stations are summarized in Table 14. Because the (NO_2/NO_x) ratios are not distributed normally, the mean values alone cannot indicate the WE/WD difference in the (NO_2/NO_x) ratios. Therefore, Table 14 lists both the mean and median values of 6-9 A.M. average (NO_2/NO_x) on weekends and weekdays.

Note that while the mean value at the Silver Spring station is lower on weekends than on weekdays, the opposite is true for the median value. The statistical test result shown in Figure 23 is consistent with the WE/WD difference found in the median values. On the average, NO_2 accounts for about 55% (59% in median) of NO_x on weekends and 59% (62% in median) on weekdays.

5.3 WE/WD DIFFERENCES IN 6-9 A.M. AVERAGE NMHC AND THC CONCENTRATIONS

Since methane is practically inert in photochemical reactions, non-methane hydrocarbons (NMHC) are used as the organic precursor of photochemical oxidants. Since adequate NMHC data are found only at four locations, total hydrocarbon (THC) data at two other locations are also included in the analysis to supplement the insufficient area coverage of NMHC data. THC data may be an indicator of NMHC when viewed on a relative basis. Because of the known unreliability of NMHC measurements at lower concentration levels and because of the poor area coverage of hydrocarbon data, the results of this section's analysis should be viewed with caution.

TABLE 14. WE/WD DIFFERENCES IN 6-9 A.M. AVERAGE (NO_2/NO_x) RATIOS

Station Name	Sun vs. TWTF					
	Mean WE level	Mean WD level	% Change WE-WD	Median WE level	Median WD level	% Change WE-WD
Bethesda	0.242	0.641	- 62%	0.163	0.666	- 76%
Silver Spring	0.482	0.496	- 3%	0.500	0.430	+ 16%
Suitland	0.752	0.800	- 6%	0.911	0.933	- 2%
Baltimore	0.808	0.691	+ 17%	0.889	0.709	+ 25%
Camden	0.611	0.584	+ 5%	0.728	0.633	+ 15%
Mamaroneck	0.448	0.416	+ 8%	0.433	0.417	+ 4%
Newark	0.618	0.533	+ 16%	0.732	0.550	+ 33%
Welfare Is.	0.451	0.594	- 24%	0.342	0.617	- 45%
8-Station Avg.	0.552	0.594	- 7%*	0.587	0.619	- 5%*

*The station-average percentage difference is computed from the station averages of WE/WD concentration levels.

5.3.1 WE/WD Differences in 6-9 A.M. Average NMHC Levels

Adequate NMHC data are found only at four monitoring sites: Suitland, Silver Spring, Baltimore, and Norristown. The first two sites are in the vicinity of Washington, D.C. The last site is located northwest of Philadelphia (see Figure 2). The weekend mean and weekday mean of 6-9 A.M. average NMHC concentrations, as well as the percentage difference of (WE-WD), are computed for the four sites under both the normal and Sunday WE/WD definitions. The results are summarized in Table 15.

Under the normal WE/WD definition (SS versus MTWTF), all four stations exhibit a considerable drop in 6-9 A.M. average NMHC levels on weekends, ranging from 24% at Norristown to 65% at Suitland. Under the Sunday WE/WD definition (Sun. versus TWTF), three stations, Suitland, Silver Spring, and Baltimore, exhibit a measurable decrease in 6-9 A.M. NMHC levels on weekends, while the Norristown station shows a slight increase on weekends. The four-station average of weekend reductions in 6-9 A.M. average NMHC concentrations is 48% under the normal WE/WD definition and 32% under the Sunday WE/WD definition.

Some of the NMHC data exhibit a large difference in variance between the weekend and weekday data sets. The ordinary t-test is based on the assumption of an equal variance for the two populations. The assumption of equal variance is questionable for the NMHC data being examined. Therefore, the Welsh t-test, which was designed to determine the significance of differences between two populations with unequal variances [Snedecor and Cochran 1976] is used to correct the bias of an

TABLE 15. WE/WD DIFFERENCES IN 6-9 A.M. AVERAGE NMHC CONCENTRATIONS

	SS vs. MTWTF				Sun. vs. TWTF			
Station Name	# Valid Obs. Days†	Mean WE level (pphm)	Mean WD level (pphm)	% Change (WE-WD)	# Valid Obs. Days†	Mean WE level (pphm)	Mean WD level (pphm)	% Change (WE-WD)
Suitland	191	30	87	- 65%	141	31	74	- 58%
Silver Spring	207	49	69	- 29%	148	56	61	- 8%
Baltimore	199	56	153	- 64%	146	60	154	- 61%
Norristown	213	87	114	- 24%	159	121	109	+ 11%
4-Station Avg.		55	106	- 48%*		67	99	- 32%*

[†] A "valid observation day" is defined as a day which has at least 2 out of 3 possible observations during the 6-9 A.M. period.

[*] The station-average percentage difference is computed from the station averages of WE/WD concentration levels.

ordinary t-test caused by the large unequal variances, whenever (maximum variance/minimum variance) $\geq$ C. Here C is the critical value which depends on the sample sizes and can be found from the above reference.

The results of statistical testing of the WE/WD differences in 6-9 A.M. average NMHC concentrations are summarized in Table 16. At the Suitland and Baltimore stations, the WE/WD differences in 6-9 A.M. average NMHC concentrations are significant; at the other two stations, Silver Spring and Norristown, the WE/WD differences are not statistically significant. The above conclusions are consistent under both normal and Sunday WE/WD definitions.

5.3.2 WE/WD Differences in 6-9 A.M. Average THC Levels

WE/WD differences in 6-9 A.M. average THC concentrations are examined for only two sites, Bethesda, Maryland, and Camden, New Jersey. The results are summarized in Table 17. The weekend mean of 6-9 A.M. average THC concentrations is lower than the weekday mean by 13% at Bethesda and 27% at Camden. The average percentage decrease (21%) in THC over the two stations is smaller than that (48%) in NMHC, which implies that ambient THC contains a considerable amount of methane, whose concentration levels change little between weekends and weekdays.

The t-test indicates that the WE/WD difference in 6-9 A.M. average THC levels is significant at both stations.

TABLE 16. STATISTICAL SIGNIFICANCE OF WE/WD DIFFERENCES IN 6-9 A.M. AVERAGE NMHC CONCENTRATIONS

Station Name	WE/WD Definition	Max. Var/Min. Var *	Test	P-Value
Suitland	New WE/WD	5.132	Welsh t-test	0.005 (Significant)
	Old WE/WD	11.565	Welsh t-test	0.000
Silver Spring	New WE/WD	1.660	t-test	0.832 (Non-Significant)
	Old WE/WD	1.072	t-test	0.275
Baltimore	New WE/WD	6.014	Welsh t-test	0.000 (Significant)
	Old WE/WD	6.960	Welsh t-test	0.000
Norristown	New WE/WD	1.192	t-test	0.728 (Non-Significant)
	Old WE/WD	1.156	t-test	0.283

*When Max. Var/Min Var. $\geq$ 1.8, the Welsh t-test is used to correct the bias of ordinary t-test caused by large unequal variances.

TABLE 17. WE/WD DIFFERENCES IN 6-9 A.M. AVERAGE THC CONCENTRATIONS

		SS vs. MTWTF			WE/WD Difference
Station Name	# Valid Obs. Days†	Mean WE level (pphm)	Mean WD level (pphm)	% Change (WE-WD)/WDx100	P-Value
Bethesda	175	174	201	- 13%	0.04 (Significant)
Camden	160	185	255	- 27%	0.0005 (Significant)
2-Station Avg.		180	228	- 21%	

†A "valid observation day" is defined as a day which has at least 2 out of 3 possible observations during the 6-9 A.M. period.

5.4 WE/WD DIFFERENCES IN CO CONCENTRATIONS

Carbon monoxide (CO) is not an oxidant precursor but is an inert gas emitted primarily by automobiles. Since ambient CO data are relatively complete, the CO data are used here as an indicator pollutant of the two precursor emissions, NO_x and NMHC, from mobile sources. Adequate CO data are found at as many as 17 monitoring sites, names and site codes for which are listed in Table 18.

The WE/WD differences in CO concentrations are examined for three overlapping time periods: 3-hr (6-9 A.M.), daytime (6 A.M.-9 P.M.), and 24-hr. The intent is to estimate the temporal variation of WE/WD differences in automotive emissions. The average CO concentrations over the three different time periods are computed for weekends, defined as Saturday and Sunday (SS), and for weekdays, defined as Monday through Friday (MTWTF).

Table 19 summarizes the WE/WD differences in CO concentrations computed for the 6-9 A.M., daytime (6 A.M.-9 P.M.), and 24-hr periods. Except for the Camden County station, the stations exhibit a considerable decrease in CO concentrations on weekends during all three time periods. The Camden County station shows the smallest WE/WD differences in CO concentrations among the 17 stations and exhibits a small increase (1%) in the 24-hr average CO levels. The Camden County site is located on the grounds of the New Jersey State Hospital, which could explain why WE CO levels are not much lower than WD levels.

TABLE 18. MONITORING STATIONS USED FOR ANALYZING CARBON MONOXIDE AIR QUALITY DATA

Metropolitan Area	Station Name	SAROAD I.D.	EPA's Site Code*	Number of Valid Observation Days†
Washington, D.C.	Bethesda	210200005 F01	S-R	266
	Silver Spring	211480006 F01	S	283
	Suitland	211560001 F01	S	277
Baltimore	Baltimore	210120018 F01	CC-C	299
	Lancaster	394660007 F01	S-R	236
Philadelphia	Camden	310720003 F01	S-R	224
	Camden Co.	310740001 F01	Ru-A	219
	Norristown	396540013 F01	S-R	202
	Philadelphia	397140026 F01	CC-C	213
New York City	Asbury Park	310060001 F01	CC-C	210
	Babylon	330280002 F01	S-I	145
	Mamaroneck	334100002 F01	CC-C	272
	Newark	313480002 F01	CC-C	198
	Welfare Is.	334680050 F01	CC	247
Boston	Medford	221220003 F01	S-I	433
	Quincy	221880002 F01	S-I	377
	Worchester	222640012 F01	CC-C	441

*Code key:

A - Agricultural
C - Commercial
CC - Center City
I - Industrial
R - Residential
Ru - Rural
S - Suburban

†A "valid observation day" is a day which has at least 10 observations for the 6 A.M.-9 P.M. period. For the 6-9 A.M. average concentration, fewer observation days may result because of stricter criteria: 2 out of 3 possible observations.

TABLE 19. WE/WD DIFFERENCES IN CO CONCENTRATIONS DURING THE 3-HR (6-9 A.M.), DAYTIME (6 A.M.-9 P.M.), AND 24-HR PERIODS

Metropolitan Area	Station Name	6-9 A.M. Average			Daytime Average	24-Hr Avg.
		Mean WE level (ppm)	Mean WD level (ppm)	% Change (WE-WD)	% Change (WE-WD)	% Change (WE-WD)
Washington, D.C.	Bethesda	0.4	0.8	- 50%	- 24%	- 19%
	Silver Spring	0.9	1.3	- 31%	- 33%	- 19%
	Suitland	1.1	2.2	- 50%	- 35%	- 11%
Baltimore	Baltimore	0.6	1.9	- 68%	- 42%	- 24%
	Lancaster	0.6	1.1	- 46%	- 38%	- 23%
Philadelphia	Camden	1.3	1.9	- 32%	- 25%	- 15%
	Camden Co.	1.6	1.7	- 6%	- 1%	+ 1%
	Norristown	0.9	1.9	- 53%	- 43%	- 29%
	Philadelphia	1.5	2.9	- 48%	- 30%	- 15%
New York City	Asbury Park	2.5	2.9	- 14%	- 12%	- 5%
	Babylon	1.2	1.8	- 33%	- 22%	- 20%
	Mamaroneck	2.6	3.2	- 19%	- 15%	- 8%
	Newark	2.3	3.6	- 36%	- 22%	- 10%
	Welfare Is.	1.8	2.0	- 10%	- 14%	- 6%
Boston	Medford	1.7	3.3	- 49%	- 27%	- 19%
	Quincy	1.9	2.6	- 27%	- 14%	- 10%
	Worchester	1.9	3.0	- 37%	- 29%	- 20%
	17-Station Avg.	1.46	2.24	- 35% *	- 25% *	- 15% *

*The station-average percentage difference is computed from the station averages of WE/WD concentration levels.

The percentage reduction of CO concentrations on weekends is the greatest during the 6-9 A.M. period and the smallest during the 24-hr period. Of the station averages, the 6-9 A.M. average CO concentration on weekends is 35% lower than that on weekdays; the daytime average CO concentration is 25% lower than that on weekdays; and the 24-hr average CO level is 15% lower.

All stations except Welfare Island and Silver Spring exhibit the largest weekend drop in the 6-9 A.M. average CO concentration, followed by the daytime average and then by the 24-hr average. At the Welfare Island and Silver Spring stations, the weekend drop in daytime average concentrations is slightly greater than the drop in the 6-9 A.M. average which, in turn, is greater than that in the 24-hr average reductions. Because of the smaller weekend drops in CO concentration during the non-6-9 A.M. time periods at all the stations other than the above two, the weekend decreases in 6-9 A.M. precursor-pollutant (NMHC, NO, and NO_2) concentrations should not be interpreted directly as the same decreases in precursor emissions. The actual decreases in precursor emissions on weekends are likely to be smaller than those found in the 6-9 A.M. average precursor concentrations.

The t-test results of the WE/WD differences in CO concentrations during the three time periods are plotted in Figure 24, using P-values. As seen from Figure 24, the WE/WD differences in both the 6-9 A.M. average CO concentrations and daytime average CO concentrations are significant at 15 out of the 17 sites examined. The two stations that do not exhibit a

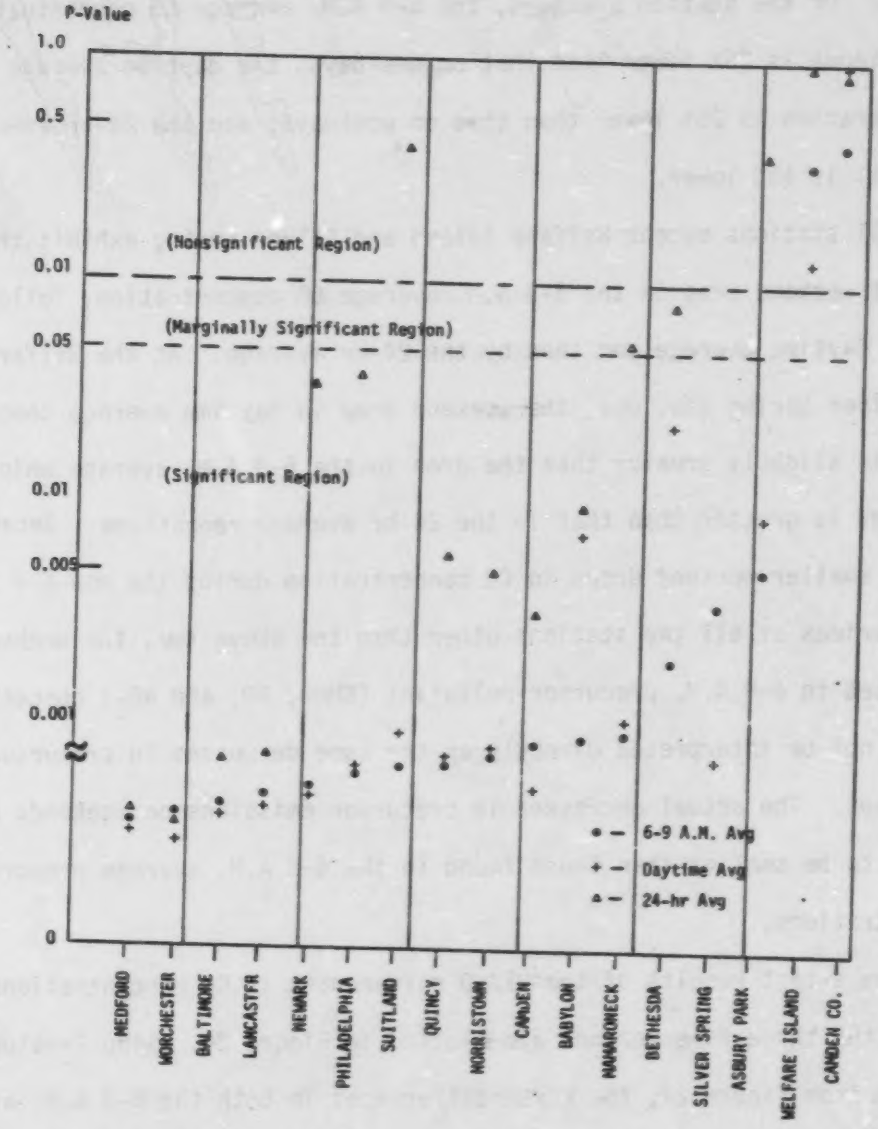


Figure 24. P-values for testing WE/WD differences in CO concentrations during the 6-9 A.M., daytime, and 24-hr periods (SS versus MTWTF).

significant WE/WD difference in CO concentrations are Welfare Island, New York, and Camden County, New Jersey. All 15 stations with significant WE/WD differences have, of course, a lower CO concentration on weekends.

In the 24-hr average CO concentrations, 11 out of 17 stations exhibit a significant WE/WD difference, with two additional stations having a marginally significant difference.

6. RESULTS AND CONCLUSIONS

The preceding sections discuss the WE/WD differences in observed daily maximum oxidant levels (Section 3), in meteorologically adjusted oxidant levels (Section 4) and in 6-9 A.M. average concentrations of oxidant precursors and carbon monoxide (Section 5). This section reviews the analysis results of the preceding sections and discusses the implications of those results for oxidant sensitivity to WE/WD changes in precursor emissions. In Section 6.1, the oxidant-precursor relationship in urban core areas is examined, and that in source/receptor areas is examined in Section 6.2. In Section 6.3, the oxidant response to WE/WD emission changes is compared with that of long-term emission changes.

6.1 OXIDANT-PRECURSOR RELATIONSHIP IN URBAN CORE AREAS

NO, NO_2, CO, and OX data are available for eight stations: Bethesda, Silver Spring, Suitland, Baltimore, Camden, Newark, Welfare Island, and Mamaroneck. Furthermore, three stations, Silver Spring, Suitland, and Baltimore, have NMHC data. These eight stations are used to examine the relationship among the WE/WD differences found in the five pollutants.

Table 20 summarizes means of daily maximum OX levels and 6-9 A.M. average concentrations of NO, NO_2, NMHC, and CO under the normal WE/WD definition. All eight stations listed in Table 20 are located within or near the large metropolitan areas (see Figure 2). Therefore, the oxidant-precursor relationships at the eight stations may be representative of those in urban core areas. In Table 20, large WE/WD differences are found

TABLE 20. WE/WD MEANS OF DAILY MAXIMUM OX CONCENTRATIONS AND 6-9 A.M. AVERAGE PRECURSOR AND CO CONCENTRATIONS AT URBAN CORE SITES (SS vs. MTWTF)

Station Name	Daily Max OX (ppb)		6-9 A.M.Avg. NO (pphm)		6-9 A.M.Avg. NO_2 (pphm)		6-9 A.M. Avg. NMHC (pphm)		6-9 A.M.Avg. CO (ppm)	
	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD
Bethesda	70	77	1.5	0.7	1.3	3.1			0.4	0.8
Silver Spr.	52	59	5.3	12.8	3.4	5.6	49	69	0.9	1.3
Suitland	73	79	0.5	1.3	3.2	5.7	30	87	1.1	2.2
Baltimore	54	59	1.0	4.6	3.4	6.6	56	153	0.6	1.9
Camden	68	70	0.9	5.4	1.8	3.3			1.3	1.9
Mamaroneck	49	54	1.9	3.2	1.5	2.0			2.6	3.2
Newark	56	49	2.2	6.3	2.9	4.0			2.3	3.6
Welfare Is.	62	61	1.4	2.4	1.8	3.2			1.8	2.0
8-Station Avg.	61	64	1.8	4.6	2.4	4.2	45	103	1.4	2.1

in 6-9 A.M. average concentrations of OX precursors and CO, but much smaller WE/WD differences are found in daily maximum OX levels. Another tendency is apparent: The higher the 6-9 A.M. NO level, the lower the daily maximum OX level. This tendency is noted among stations but is not always noted between weekends and weekdays.

The percentage changes in each pollutant concentration between weekends and weekdays are computed and summarized in Table 21. On the average, the weekend level of 6-9 A.M. average NO concentrations is 60% lower than the weekday level, while the NO_2 weekend level is 42% lower. Since NO_x concentration is approximately equal to the sum of NO and NO_2 concentrations, the weekend level of 6-9 A.M. NO_x concentrations should be lower than the weekday level by some similar percentage, say, 50%.

NMHC data are available for three stations only: Silver Spring, Suitland, and Baltimore. The three-station average NMHC level in 6-9 A.M. concentrations is 56% lower on weekends than on weekdays. Because fewer stations were used, an eight-station average decrease in 6-9 A.M. NMHC concentration on weekends may be different from the three-station average value. In any case, the weekend precursor levels are lower than the weekday levels by about 50% in 6-9 A.M. average NO_x concentrations and 50% to 60% lower in 6-9 A.M. average NMHC concentrations. Under the above decreases in 6-9 A.M. precursor concentrations, the eight-station average drop in daily maximum OX concentrations on weekends is only 5%.

TABLE 21. PERCENTAGE CHANGES (WE-WD) IN DAILY MAXIMUM OX CONCENTRATIONS AND 6-9 A.M. AVERAGE PRECURSOR AND CO CONCENTRATIONS AT URBAN CORE SITES (SS vs. MTWTF)

Station Name	Daily Max	6-9 A.M. Average			
	OX	NO	NO_2	NMHC	CO
Bethesda	- 9%	+134%	- 59%		- 50%
Silver Spring	- 13%	- 58%	- 39%	- 29%	- 31%
Suitland	- 8%	- 60%	- 44%	- 65%	- 50%
Baltimore	- 9%	- 79%	- 48%	- 64%	- 68%
Camden	- 2%	- 83%	- 47%		- 32%
Mamaroneck	- 8%	- 40%	- 22%		- 19%
Newark	+ 13%	- 65%	- 27%		- 36%
Welfare Is.	+ 1%	- 43%	- 42%		- 10%
8-Station Avg.*	- 5%	- 60%	- 42%	- 56%	- 35%

*The station-average percentage difference is computed from the station averages of WE/WD concentration levels listed in Table 20.

Table 22 summarizes means of daily maximum oxidant concentrations and of 6-9 A.M. average precursor concentrations for the Sunday WE/WD definition. As noted in Figures 6 and 7, the WE/WD differences in daily max OX levels are slightly greater for the Sunday definition than for the normal definition. However, a similar magnification of the WE/WD differences is not seen in the precursor-pollutant levels.

Table 23 briefly lists the percentage differences for oxidants and precursors using the Sunday WE/WD definition. Except for NO at the Bethesda station, the 6-9 A.M. precursor levels are consistently lower on weekends among the eight stations. The daily maximum oxidant levels are also consistently lower on weekends except for the Newark station, which exhibits an increase (12%) in daily max OX levels. The station average reductions on weekends are 9% for daily max OX levels and 67%, 48%, and 49%, respectively, for 6-9 A.M. average NO, NO_2, and NMHC levels. Since only three stations have NMHC values, the average percentage reduction for NMHC, 49%, is a less reliable estimate than those for NO and NO_2.

A comparison of Tables 21 and 23 indicates that, in 6-9 A.M. average NO and NO_2 levels, the percentage decreases for Sundays alone are 12% to 14% greater than those for Saturdays and Sundays combined. In daily maximum OX levels, the percentage decrease for Sundays only is nearly twice as large as that for Saturdays and Sundays combined. For NMHC, the percentage decrease on Sundays is slightly smaller than that on Saturdays and Sundays combined. However, because of the small number of stations (three) used, such a difference may be due to sample fluctuation.

TABLE 22. WE/WD MEANS OF DAILY MAX OX AND OF 6-9 A.M. AVERAGE LEVELS OF NO, NO_2, AND NMHC: SUN. VERSUS TWTF

Station Name	Daily Max OX(ppb)		6-9 A.M. Average Concentration					
			NO (pphm)		NO_2 (pphm)		NMHC (pphm)	
	WE	WD	WE	WD	WE	WD	WE	WD
Bethesda	64	76	2.33	0.66	1.09	3.00		
Silver Spr.	51	59	3.63	13.00	3.00	5.61	56	61
Suitland	74	79	0.10	1.43	3.05	5.73	31	74
Baltimore	48	57	0.87	4.38	2.97	6.66	60	154
Camden	68	69	0.85	5.39	1.75	3.31		
Mamaroneck	46	54	1.37	3.39	1.16	2.05		
Newark	56	49	1.84	6.58	3.02	4.18		
Welfare Is.	57	63	1.32	2.39	1.69	3.27		
8-Station Avg.	58	63	1.54	4.65	2.22	4.23	49	96

TABLE 23. PERCENTAGE DIFFERENCE (WE - WD) IN DAILY MAX OX AND IN 6-9 A.M. AVERAGE LEVELS OF NO, NO_2, AND NMHC: SUN. VERSUS TWTF

Station Name	OX	NO	NO_2	NMHC
Bethesda	- 17%	+252%	- 64%	
Silver Spring	- 13%	- 72%	- 47%	- 8%
Suitland	- 6%	- 93%	- 47%	-59%
Baltimore	- 16%	- 80%	- 55%	-61%
Camden	- 2%	- 84%	- 47%	
Mamaroneck	- 14%	- 60%	- 43%	
Newark	+ 12%	- 72%	- 28%	
Welfare Is.	- 9%	- 45%	- 48%	
8-Station Avg.*	- 9%	- 67%	- 48%	-49%

*The station-average percentage difference is computed from the station averages of WE/WD concentration levels.

Regardless of the WE/WD definition used, WE oxidant reductions at the urban sites are not nearly as large as those associated with early-morning precursors. To some degree, this may be expected. In the source-intensive urban areas, emissions are generally high throughout a weekday due to traffic. Because NO is a very effective scavenger of oxidants, it is very likely that oxidant levels in the urban area may actually be suppressed during the week. (Recall from Section 3 that weekday maximum daily oxidant levels within urban areas were generally lower than those outside.) The early-morning reductions in NO and the daytime reductions in CO on weekends indicate that NO levels in the urban areas may very well be lower throughout the weekend, leaving less NO available for oxidant scavenging. Consequently, in the urban core, any reductions in precursor emissions and subsequent oxidant formation upwind of the urban area may be offset by the lowered scavenging effect on weekends.

6.2 OXIDANT-PRECURSOR RELATIONSHIP IN DOWNWIND AREAS

The preceding subsection discusses the relationship between weekend oxidant reductions and weekend precursor reductions at the eight urban core sites. However, because a higher oxidant level is usually found in the downwind area rather than in the urban source area, it would also be useful to contrast weekend reductions in urban precursor levels with oxidant reductions in downwind areas.

By referring to Figure 2, we have formed source-receptor pairs in Table 24 to compare the weekend precursor reduction at the source site with the weekend oxidant reduction at the downwind receptor site. Because ambient precursor data are available at fewer sites than oxidant data, each source site is paired with more than one downwind receptor site. By considering the location of each monitoring station and the availability of precursor data, we chose to use the Baltimore station as the urban-source site for the Washington, D.C.-Baltimore metropolitan area and the Camden station for the Philadelphia metropolitan area. The Newark-New York and Boston metropolitan areas are represented by the Newark and Medford stations, respectively. The downwind receptor stations listed in Table 22 were selected by considering the geographical location and the WE/WD oxidant behavior (a consistently lower weekend level is used as the criterion).

Table 24 indicates that while the 6-9 A.M. weekend urban precursor levels are 64% to 83% lower in the four metropolitan areas (five if the Washington, D.C., and Baltimore areas are counted separately), the weekend downwind oxidant levels are only 7% to 14% lower. On the average over the four regions, the NO and NMHC levels are 75% and 64% lower, respectively, on weekends. Those reductions in 6-9 A.M. precursor levels bring about 11%-12% reductions in daily maximum oxidant levels. In Table 24, percentage reductions in 6-9 A.M. and daytime (6 A.M.-9 P.M.) CO levels are also presented to facilitate some estimate of precursor reductions for those

TABLE 24. WEEKEND REDUCTIONS IN 6-9 A.M. URBAN PRECURSOR LEVELS AND DOWNWIND DAILY MAX OX LEVELS (SS vs. MTWTF)

Metropolitan Area	% Changes in Urban Precursor Levels					% Changes in Downwind OX Levels		
	Station Name	6-9 AM NO	6-9 AM NMHC	6-9 AM CO	Daytime CO	Station Name	OX	Regional Avg.[a]
Washington D.C.-Baltimore	Baltimore	-79%	-64%	-68%	-42%	Bethesda Gaithersburg[b] Silver Spring Suitland[b] Lancaster	-9% -4% -13% -8% -10%	-9% (-10%)[c]
Philadelphia	Camden	-83%	NA	-32%	-25%	Norristown[b] Camden Co.	-9% -14%	-12% (-14%)[c]
Newark-New York	Newark	-65%	NA	-36%	-22%	Greenwich Middletown Danbury Mamaroneck	-15% -11% -18% -8%	-14%
Boston	Medford	NA	NA	-49%	-27%	Salem Quincy[b]	-12% -4%	-7% (-12%)[c]
4-Region Avg.[a]		-75%	-64%	-45%	-27%			-11% (-12%)[c]

NA Data are not available.

a. The regional average percentage difference is computed from the station averages of WE/WD concentration levels.

b. These stations are located somewhat off the typical downwind area.

c. Regional average value when nontypical downwind stations are excluded.

stations at which data are not available for one or both of the two precursor pollutants. The weekend reductions in CO levels are somewhat smaller than those in the two precursors. However, their percentage reductions are still much greater than those in downwind oxidant levels.

The 11%-to-12% reduction in downwind oxidant levels is small, compared with the 64%-to-75% reduction in 6-9 A.M. urban precursor levels. However, the percentage reduction in downwind oxidant levels is more than twice as large as that in urban oxidant levels (see Table 21). These greater responses of downwind oxidant levels to changes in precursor levels can be seen from Table 25, where percentage changes in weekend oxidant levels are computed for stations in each of three types of regions: upwind areas, metropolitan areas, and downwind areas. Although the grouping of stations into each of the three types of region is somewhat arbitrary, the following general pattern emerges from such a spatial grouping of stations:

- The oxidant levels in urban source-intensive areas are relatively low, and the weekend reductions are also small.
- The oxidant levels in areas downwind of a large metropolitan area tend to be higher than those within the metropolitan area. The weekend reductions in these downwind areas are also much greater than those within the metropolitan area.
- The oxidant levels and weekend reductions in the upwind area are slightly higher than those in the metropolitan area itself, but are substantially lower than those in the downwind area.

The above results should be viewed with some caution. The analysis of precursor data indicated substantial reductions in 6-9 A.M. concentrations in urban areas on weekends. These 6-9 A.M. concentrations are thought

TABLE 25. WE/WD CHANGES IN DAILY MAXIMUM OXIDANT LEVELS IN REGIONS UPWIND OF, DOWNWIND OF, AND WITHIN THE LARGE METROPOLITAN AREAS (SS VS. MTWTF)

Region	Station Name	% Difference (WE - WD)	Regional Average		
			% Difference	WE Level (ppb)	WD Level (ppb)
Upwind Areas	Bethesda (BE)*	-9	-7%	65	69
	Gaithersburg(GA)*	-4			
	Asbury Park (AP)	-4			
	Worchester(WO)	-3			
	Norristown(NO)*	-9			
Metropolitan Areas	Suitland (SU)*	-8	-2%	59	60
	Baltimore (BA)	-9			
	Philadelphia(PH)	+2			
	Camden (CA)	-2			
	Newark (NE)	+13			
	Welfare Is.(WI)	+1			
	Mamaroneck(MA)*	-8			
	Medford (ME)	+2			
	Quincy (QU)*	-4			
Downwind Areas	Silver Spring(SS)*	-13	-12%	67	76
	Lancaster (LA)	-10			
	Camden Co.(CC)	-14			
	Babylon (BB)*	-7			
	Greenwich(GR)	-15			
	Danbury (DA)	-18			
	Middletown(MI)	-11			
	Salem (SA)	-12			

*This station could be classified differently.

to be indicative of the oxidant-forming potential of a city. However, due to the limited spatial resolution of precursor data, the changes in concentrations outside the urban area are unknown. Precursor emissions occurring outside the urban area can affect the oxidant levels formed on any given day. A second precautionary note is that the 6-9 A.M. reductions in weekend precursor levels may be misleadingly high as a result of changes in temporal emission patterns. As Table 19 suggests, reductions in weekend CO levels are considerably less than implied by the 6-9 A.M. levels alone.

6.3 WE/WD OXIDANT CHANGE VS. LONG-TERM OXIDANT CHANGE

By comparing the WE/WD oxidant change with the long-term oxidant change occurring in the Los Angeles region, this subsection gives a brief overview of the effectiveness of simultaneous control of NO_x and NMHC for controlling oxidant air pollution. The hydrocarbon controls employed in the Los Angeles area in the late 1960s brought about a remarkable oxidant improvement in the source-intensive areas [Horie and Trijonis 1977]. The 15%-to-18% reduction in NMHC and the 35%-to-36% increase in NO_x brought over a 30% improvement in daily maximum oxidant levels during the 1965-1974 period. Over that 10-year period, the oxidant improvements in the source-intensive western portion of the basin were greater than those in the downwind, eastern portion of the basin [Trijonis et al. 1976].

On weekends, the eight-station average 6-9 A.M. NO and NO_2 levels are, respectively, 60% and 42% lower than the weekday level, while the three-station average 6-9 A.M. NMHC level is 56% lower than the weekday level (Table 21).

These reductions in morning precursor levels brought about a 5% (Saturdays and Sundays) to 9% (Sundays) improvement in daily maximum oxidant levels in the source-intensive metropolitan areas. A slightly greater improvement (about 12%) occurred in areas downwind of the metropolitan areas.

Compared with the Los Angeles example, the weekend oxidant improvement that is brought about by a simultaneous reduction in NO_x and NMHC is much less dramatic. In Los Angeles, there has been a reduction in NMHC and an increase in NO_x, thereby resulting in a lower NMHC/NO_x ratio. These three factors appear to have contributed synergistically to the 30% reduction in daily maximum oxidant levels. On the other hand, about the same percentage reductions in both NMHC and NO_x occurred on weekends, thereby leaving the NMHC/NO_x ratio virtually unchanged. Therefore, the reduction in NMHC alone contributed to lowering oxidant levels on weekends.

The above examples, however, should not be used to compare the effectiveness of hydrocarbon controls and that of simultaneous control of NO_x and NMHC. Because the Los Angeles area has higher oxidant levels than are found in the northeast United States, a relative contribution of transported oxidant to the ambient oxidant level would be smaller in the Los Angeles area than in the northeast. As a result, the effect of the same oxidant control on ambient oxidant level will show up more in the Los Angeles area than in the northeast United States.

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APPENDIX A

STUDENT T-TEST AND WELSH T-TEST

Let $\overline{x}_1$ and $\overline{x}_2$ be sample means of n_1 weekend values and n_2 weekday values, respectively, and let s_1^2 and s_2^2 be sample variances of the weekend values and the weekday values, respectively. Then, t corresponding to the differences in sample means is computed by

$$t = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{s^2/n_1 + s^2/n_2}} ,$$

where s^2 is the pooled variance, which, in turn, is given by

$$s^2 = \frac{(n_1-1)\, s_1^2 + (n_2-1)\, s_2^2}{(n_1-1) + (n_2-1)} .$$

The two-tailed probability for the t-value computed and the $(n_1 + n_2 - 2)$ degrees of freedom, which can be found in most statistical textbooks, is compared with the chosen confidence level (1-p). If $p \leq 0.05$, the difference between the two means $\overline{x}_1$ and $\overline{x}_2$ is significant, i.e., not merely due to chance. If $0.05 < p \leq 0.10$, the difference between the two means is marginally significant. If $p > 0.10$, the difference is insignificant, i.e., likely to be caused by mere chance.

The preceding test is based on the assumption that the two population variances are the same. When the two population variances differ quite a lot, a Welsh t-test, instead of an ordinary t-test, has to be used. The Welsh t-statistic is computed by

$$t' = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{s_1^2/n_1 + s_2^2/n_2}} \quad .$$

The significance level of t' is, approximately,

$$\frac{(w_1 t_1 + w_2 t_2)}{(w_1 + w_2)} \quad ,$$

where $w_1 = s_1^2/n_1$, $w_2 = s_2^2/n_2$, and t_1 and t_2 are the significance levels of t found in the t-table for (n_1-1) and (n_2-1) degrees of freedom, respectively.

APPENDIX B

WILCOXON RANK SUM TEST

The significance probabilities (the P-value) of W_s can be obtained by the use of a normal approximation. The mean of W_s can be approximated by $M = 1/2n(n+m+1)$, and the variance of W_s can be approximated by $VAR = [mn(m+n+1)]/12$. Thus the P-value of $Z = (W_s-M)/\sqrt{VAR}$ can be found in the normal table.

APPENDIX C

CONFIDENCE INTERVAL FOR THE MEDIAN

Let $\{Y_i\}$, $i=1, \ldots n$ be a sample of size n. Let $\hat{Y}$ be the median. Then a robust confidence interval for the median can be computed by the following procedure, suggested by Alan M. Gross ("Confidence Interval Robustness with Long-Tailed Symmetric Distributions," JASA, Vol. 71, June 1976, pp. 409-416) and simplified by John Tukey and Mosteller "Data Analysis and Regression".

Procedure:

1. Let $\hat{Y}$ be the median.
2. I = Interquantile range

   = upper hinge-lower hinge.
3. Compute the standardized value

$$U_i = \frac{Y_i - \hat{Y}}{9xI} \quad .$$

4. Compute the asymptotic variance for the median:

$$\hat{\text{Var}}\ \hat{Y} = \frac{\Sigma'(y-\hat{y})^2\ (1-u^2)^4}{[\Sigma'(1-u^2)(1-5u^2)][-1+\Sigma'(1-u^2)(1-5u^2)]} \quad .$$

5. The confidence interval, then, is

$$\hat{Y} \pm t_v \sqrt{\hat{\text{Var}}\ \hat{Y}} \quad ,$$

where t_v is the t percentage with df

$$v = 0.7(n-1) \quad .$$

APPENDIX D

THE AID DECISION-TREE PROGRAM

The purpose of the AID program is to illustrate the relationship between a dependent variable A and independent variables x, y, z, ..., by dividing the available data into classes (defined by the independent variables) in such a way as to best explain the variance in A. The data base for AID consists of a set of "n" measurements: $A_1, \ldots, A_n$ and $x_1, \ldots, x_n$; $y_1, \ldots, y_n$; $z_1, \ldots, z_n$; etc. Each of the independent variables is represented by discrete numbers: e.g., x might assume values of 1, 2, 3, or 4; y might assume values of 1, 2, 3, 4, 5, 6, or 7; z might assume values of 1, 2, 3, 4, or 5; etc. To achieve discreteness, the raw data for the independent variables are usually divided in ranges. For example, if the variable z represents wind speed (WS), one might define $z = 1$ if $0 \leq WS < 3$ mph; $z = 2$ if $3 \leq WS < 7$ mph; $z = 3$ if $7 \leq WS < 15$ mph; $z = 4$ if $15 \leq WS < 25$ mph; and $z = 5$ if 25 mph $\leq WS$.

The first step of AID determines the independent variable that can be split into two groups (say, $z = 1$ and 4 versus $z = 2, 3,$ and 5) which maximize the residual sum of squares (RSS) explained in the dependent variable. If the two groups (G_1 and G_2) have group means $\overline{A1}$ and $\overline{A2}$, then the RSS explained by splitting the data is

$$\Delta RSS = RSS_0 - RSS_1 - RSS_2 \ ,$$

where

$$RSS_0 = \sum_{j=1}^{n} (A_j - \overline{A})^2 = \text{RSS for entire data set;}$$

$$RSS_1 = \sum_{G_1} (A_j - \overline{A_1})^2 = \text{RSS for } G_1\text{; and}$$

$$RSS_2 = \sum_{G_2} (A_j - \overline{A_2})^2 = \text{RSS for } G_2.$$

The program considers all possible partitions of the data among all the independent variables and selects the specific independent variable and specific partition that maximizes ΔRSS.

The partitioning process is repeated on each of the groups G_1 and G_2 to yield subgroups. These and all further subgroups are divided until either 1) no subgroup can be split to achieve a ΔRSS above a preset lower bound, 2) further division will produce a subgroup with number of elements less than a preset bound, or 3) the number of terminal subgroups reaches a prespecified limit.

APPENDIX E

BINARY DECISION TREES DEVELOPED FOR CLASSIFYING DAILY MAXIMUM OX LEVEL BY METEOROLOGY

This appendix shows the 22 AID trees analyzed. Briefly listed are meteorological variables and their corresponding symbols used in the tree structure.

1. T_{max} - Maximum Temperature (^oF)
2. T_{avg} - Average Temperature (^oF)
3. P - Surface Pressure (mb)
4. Vis - Visibility (miles)
5. WD - Wind Direction (^{o})
6. WS - Wind Speed (knots)
7. MH - Mixing Height (meters)
8. $\overline{V}$ - Mean wind speed through the mixing layer (m/sec)

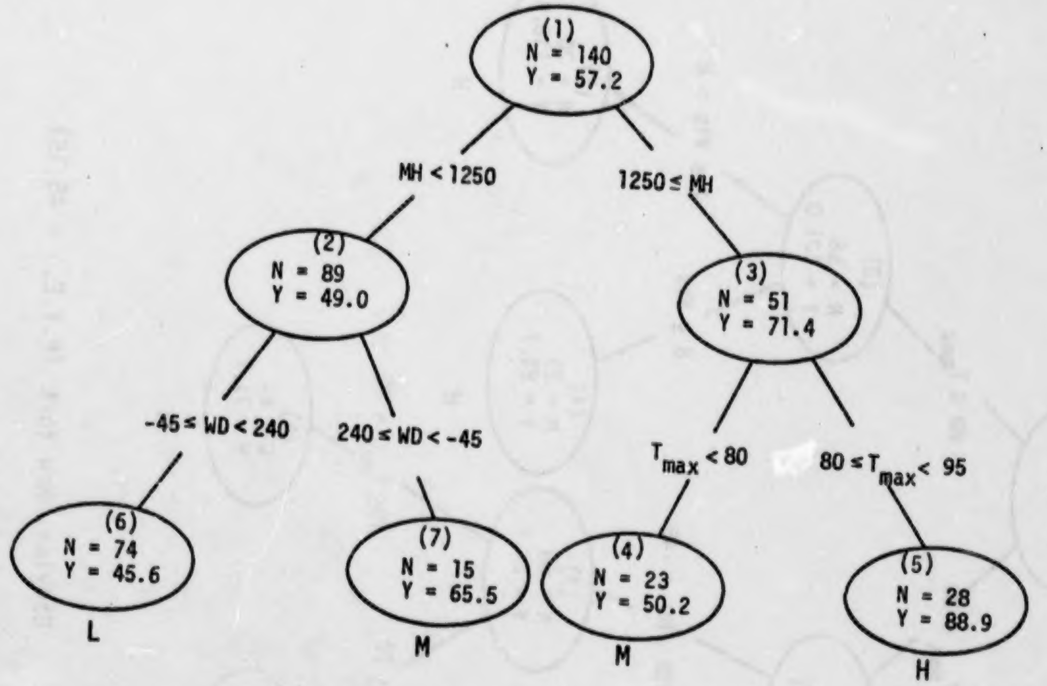
The other symbols included in each decision tree are:

H: indicating that the terminal node belongs to the high class.

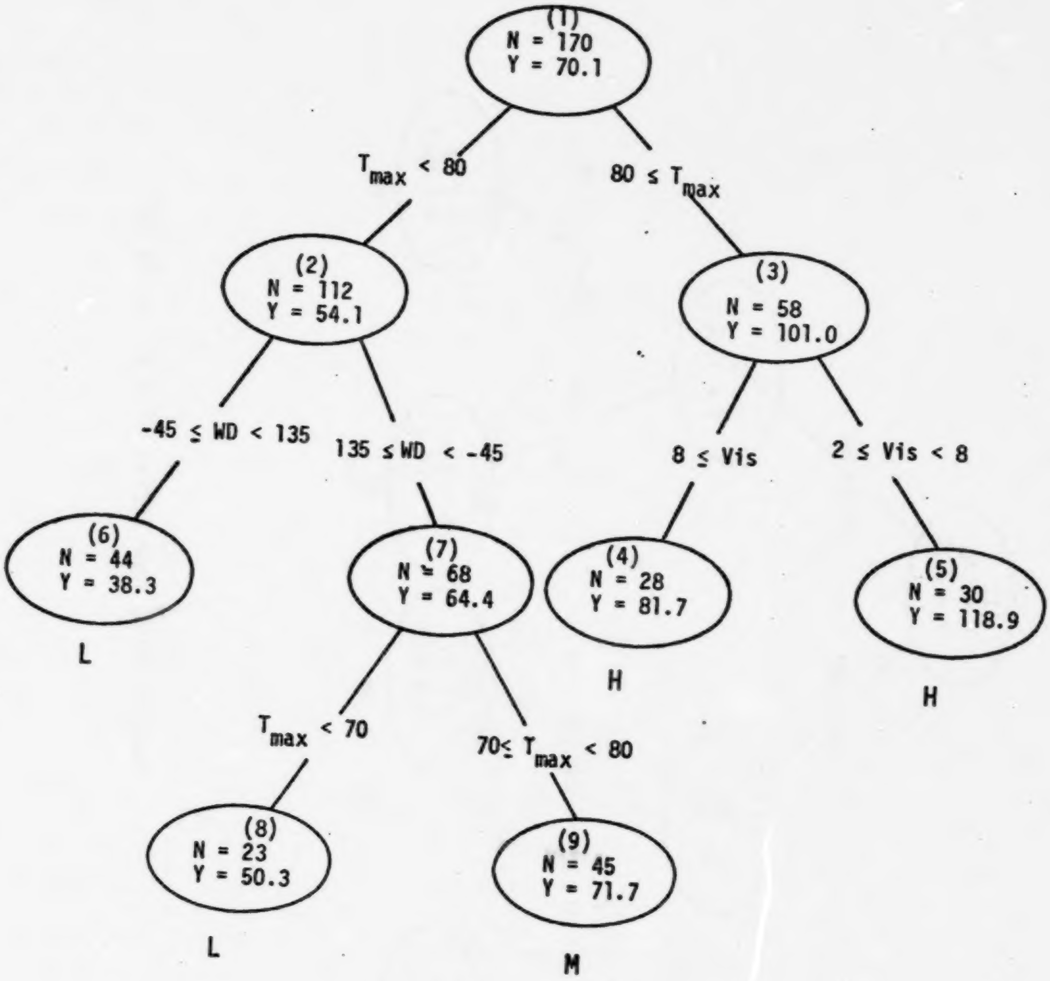
M: indicating that the terminal node belongs to the middle class.

L: indicating that the terminal node belongs to the low class.

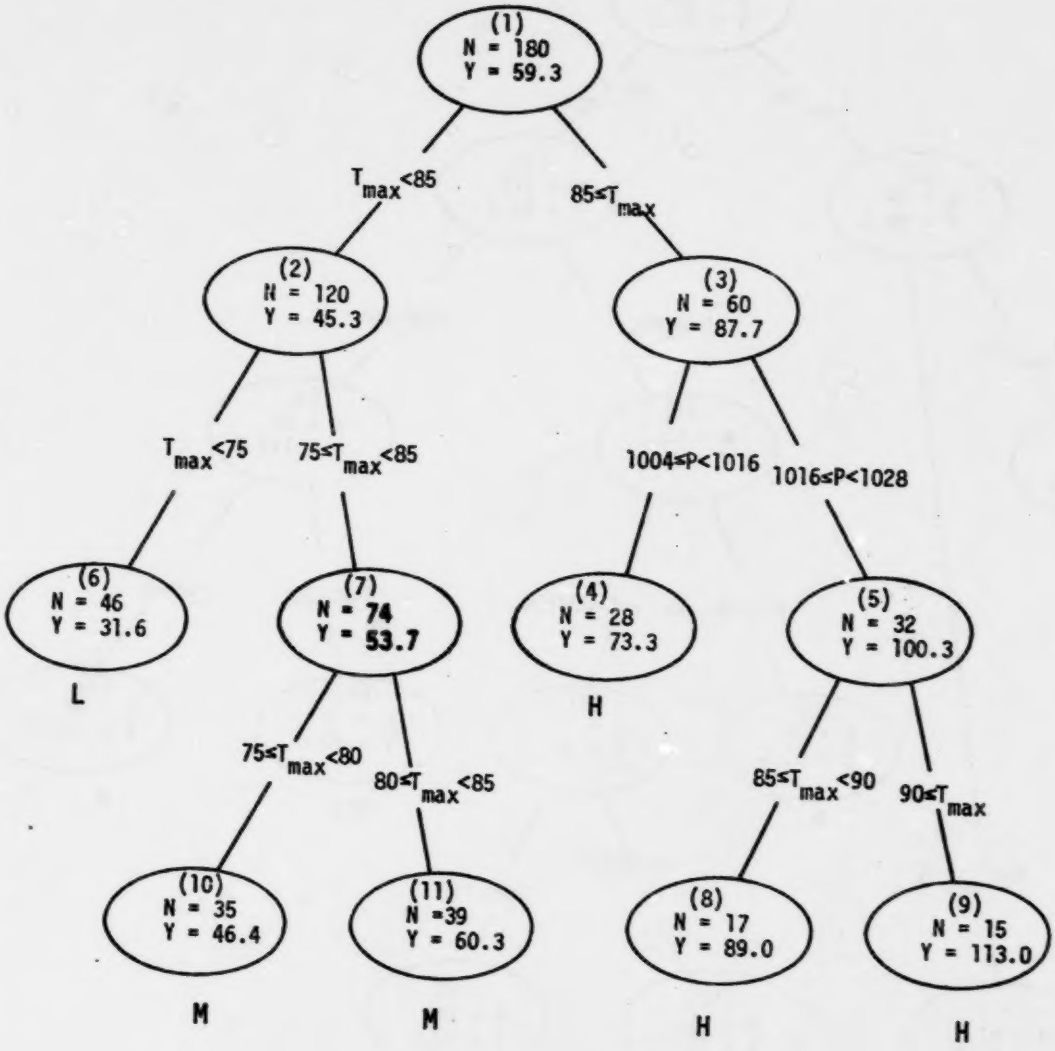
P.V.E.: Percentage of variance explained by the decision tree.


(1)
N = 140
Y = 57.2
MH < 1250
1250 ≤ MH
(2)
N = 89
Y = 49.0
(3)
N = 51
Y = 71.4
-45 ≤ WD < 240
240 ≤ WD < -45
T_max < 80
80 ≤ T_max < 95
(6)
N = 74
Y = 45.6
L
(7)
N = 15
Y = 65.5
M
(4)
N = 23
Y = 50.2
M
(5)
N = 28
Y = 88.9
H

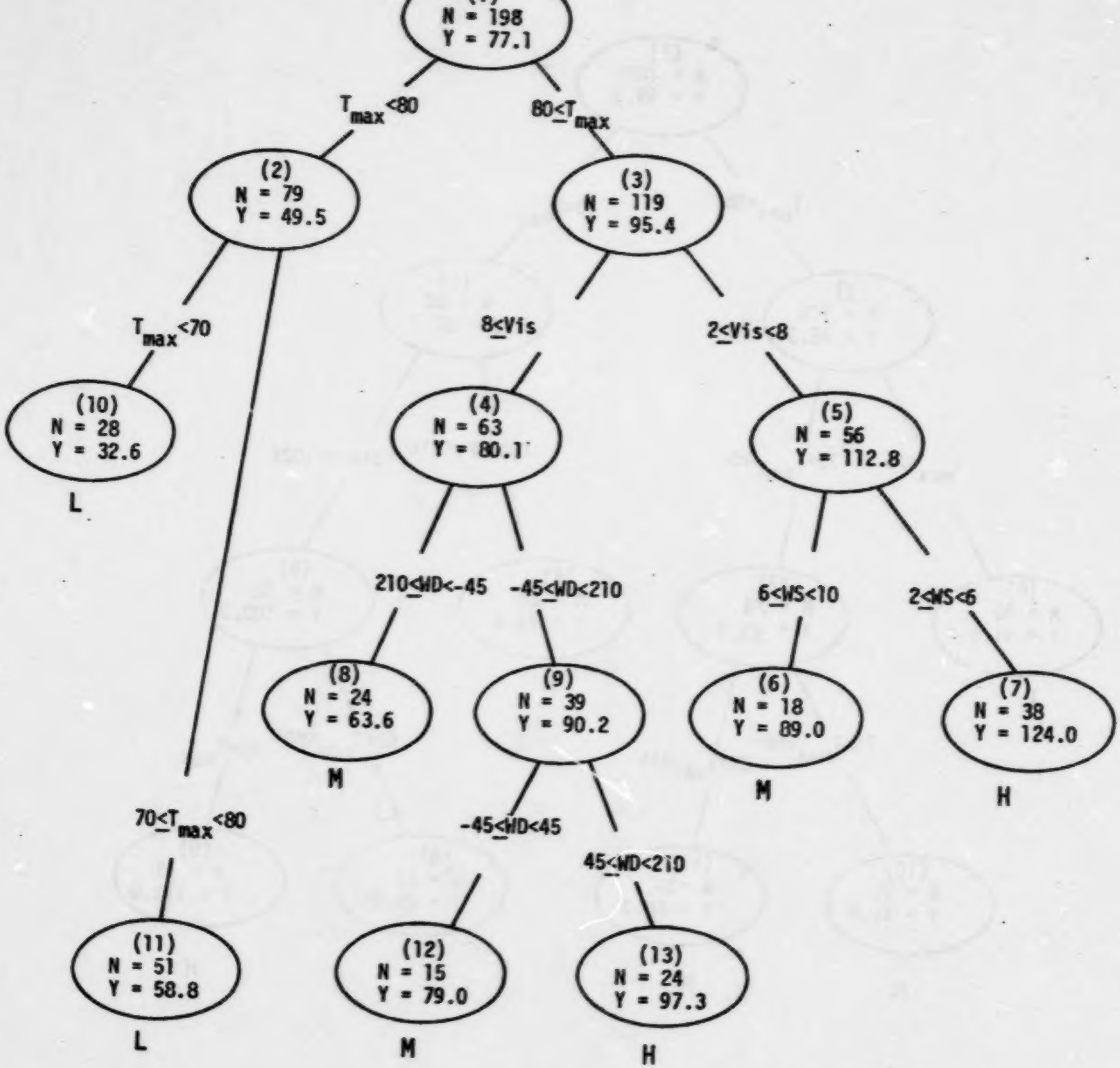
Asbury Park, New Jersey (P.V.E. = 33.3%)


(1)
N = 170
Y = 70.1
Tmax < 80
80 ≤ Tmax
(2)
N = 112
Y = 54.1
(3)
N = 58
Y = 101.0
-45 ≤ WD < 135
135 ≤ WD < -45
8 ≤ Vis
2 ≤ Vis < 8
(6)
N = 44
Y = 38.3
L
(7)
N = 68
Y = 64.4
(4)
N = 28
Y = 81.7
H
(5)
N = 30
Y = 118.9
H
Tmax < 70
70≤ Tmax < 80
(8)
N = 23
Y = 50.3
L
(9)
N = 45
Y = 71.7
M

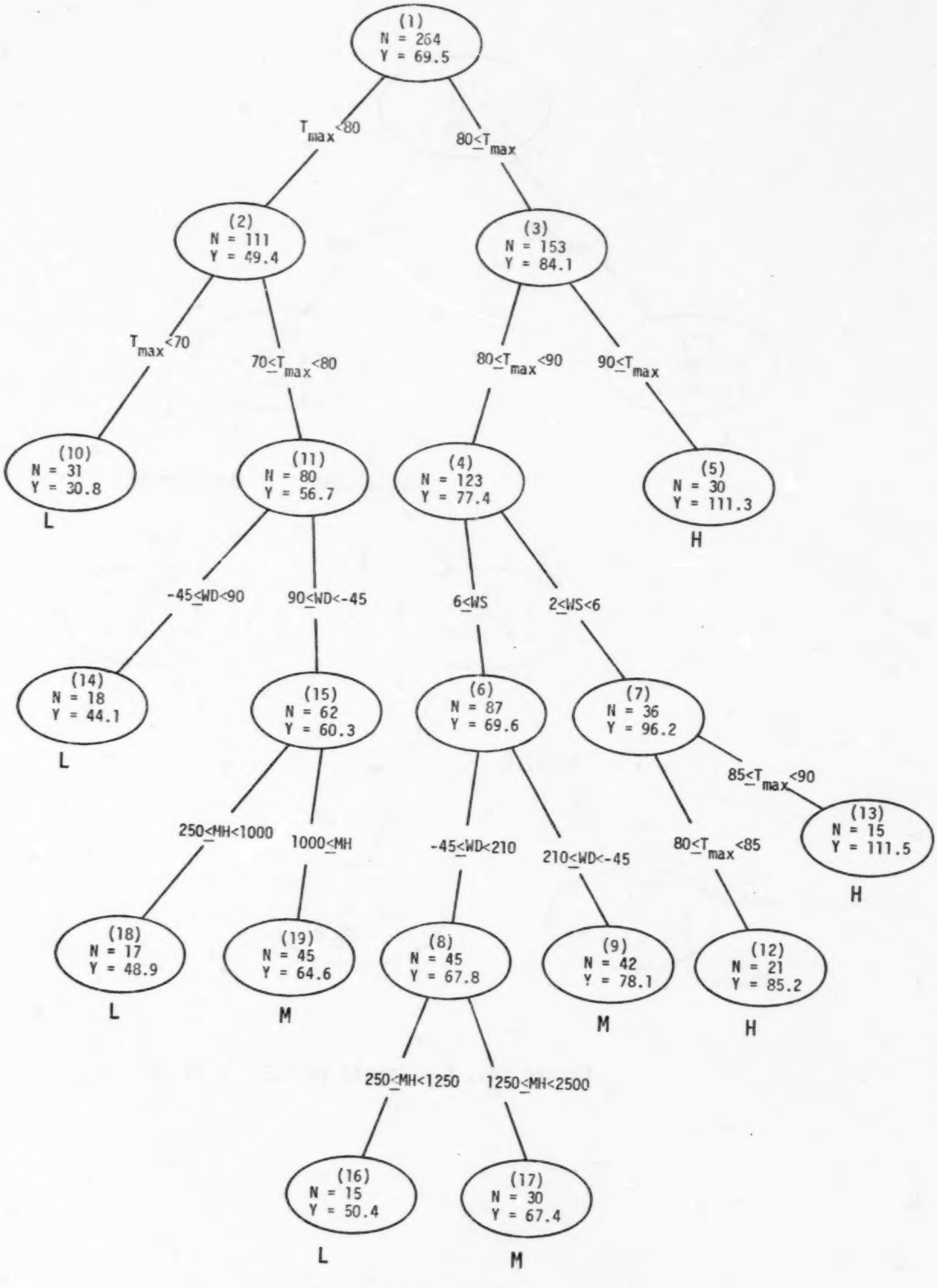
Babylon, New York (P.V.E. = 45.1%)


(1)
N = 180
Y = 59.3
T_{max}<85
85≤T_{max}
(2)
N = 120
Y = 45.3
(3)
N = 60
Y = 87.7
T_{max}<75
75≤T_{max}<85
1004≤P<1016
1016≤P<1028
(6)
N = 46
Y = 31.6
L
(7)
N = 74
Y = 53.7
(4)
N = 28
Y = 73.3
H
(5)
N = 32
Y = 100.3
75≤T_{max}<80
80≤T_{max}<85
85≤T_{max}<90
90≤T_{max}
(10)
N = 35
Y = 46.4
M
(11)
N =39
Y = 60.3
M
(8)
N = 17
Y = 89.0
H
(9)
N = 15
Y = 113.0
H

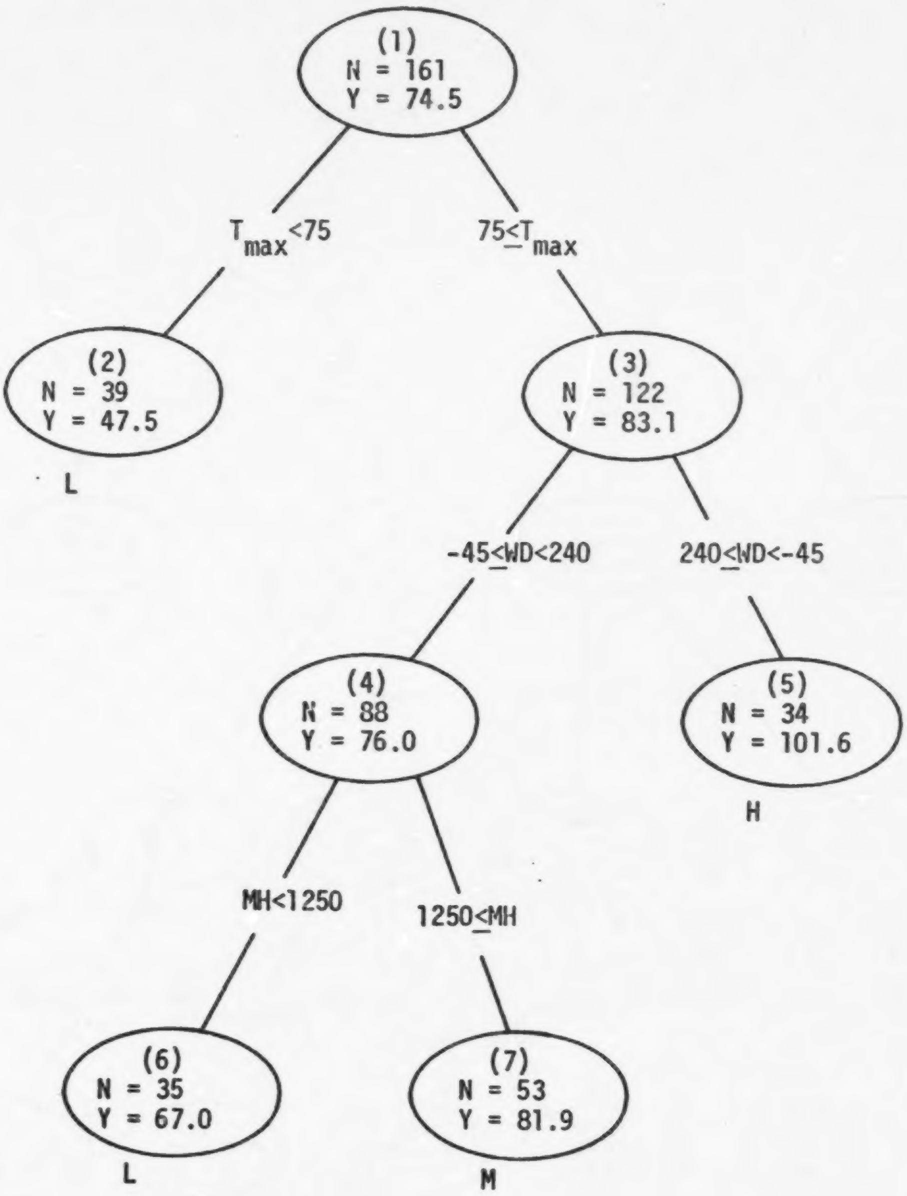
Baltimore, Maryland (P.V.E, = 48.4%)


(1)
N = 198
Y = 77.1
$T_{max}<80$
$80\leq T_{max}$
(2)
N = 79
Y = 49.5
(3)
N = 119
Y = 95.4
$T_{max}<70$
$8\leq Vis$
$2\leq Vis<8$
(10)
N = 28
Y = 32.6
L
(4)
N = 63
Y = 80.1
(5)
N = 56
Y = 112.8
$210\leq WD<-45$
$-45\leq WD<210$
$6\leq WS<10$
$2\leq WS<6$
(8)
N = 24
Y = 63.6
M
(9)
N = 39
Y = 90.2
(6)
N = 18
Y = 89.0
M
(7)
N = 38
Y = 124.0
H
$70\leq T_{max}<80$
$-45\leq WD<45$
$45\leq WD<210$
(11)
N = 51
Y = 58.8
L
(12)
N = 15
Y = 79.0
M
(13)
N = 24
Y = 97.3
H

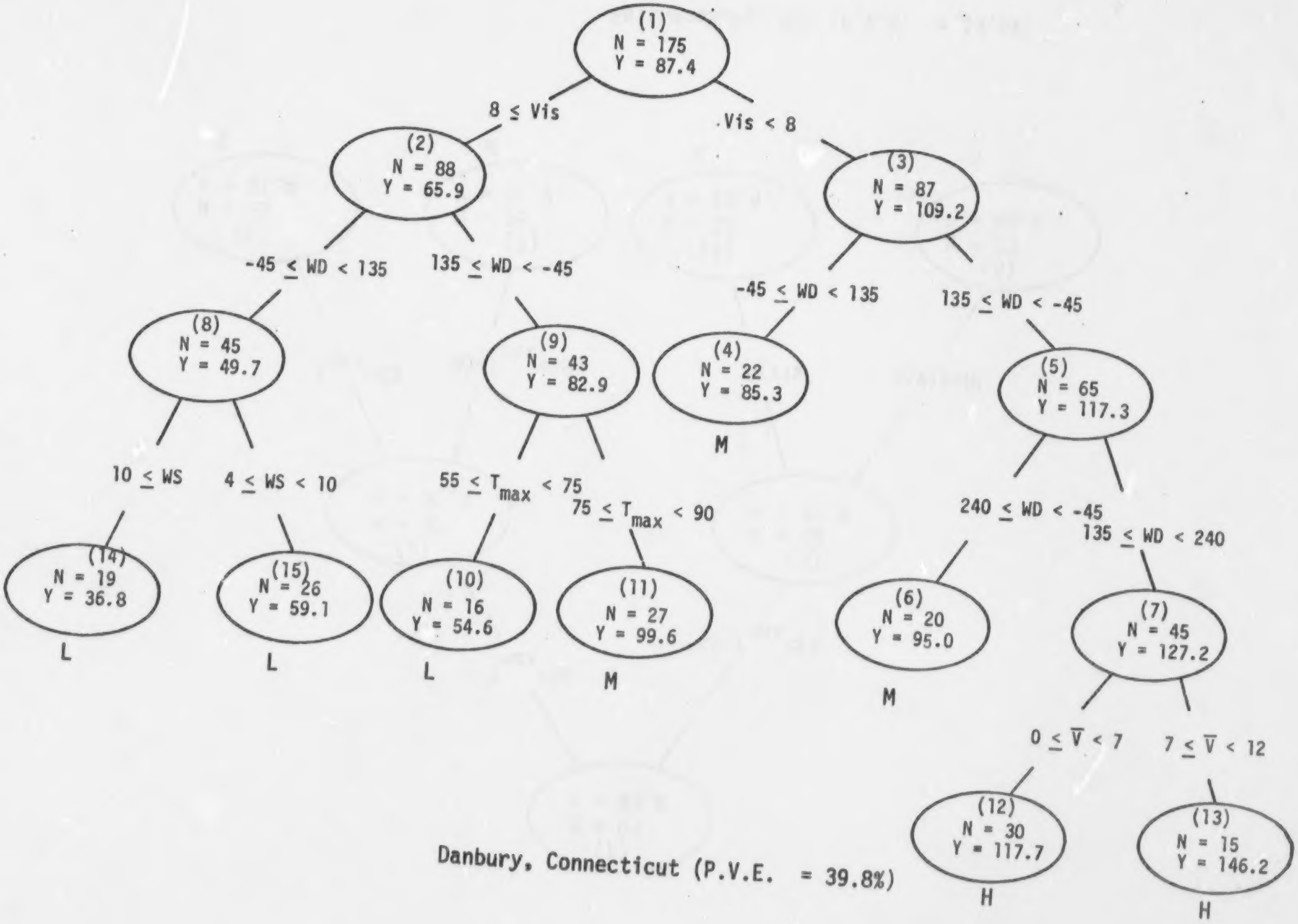
Bethesda, Maryland (P.V.E. = 48.0%)


(1)
N = 264
Y = 69.5
$T_{max}<80$
$80\le T_{max}$
(2)
N = 111
Y = 49.4
(3)
N = 153
Y = 84.1
$T_{max}<70$
$70\le T_{max}<80$
$80\le T_{max}<90$
$90\le T_{max}$
(10)
N = 31
Y = 30.8
L
(11)
N = 80
Y = 56.7
(4)
N = 123
Y = 77.4
(5)
N = 30
Y = 111.3
H
$-45\le WD<90$
$90\le WD<-45$
$6\le WS$
$2\le WS<6$
(14)
N = 18
Y = 44.1
L
(15)
N = 62
Y = 60.3
(6)
N = 87
Y = 69.6
(7)
N = 36
Y = 96.2
$85\le T_{max}<90$
(13)
N = 15
Y = 111.5
H
$250\le MH<1000$
$1000\le MH$
$-45\le WD<210$
$210\le WD<-45$
$80\le T_{max}<85$
(18)
N = 17
Y = 48.9
L
(19)
N = 45
Y = 64.6
M
(8)
N = 45
Y = 67.8
(9)
N = 42
Y = 78.1
M
(12)
N = 21
Y = 85.2
H
$250\le MH<1250$
$1250\le MH<2500$
(16)
N = 15
Y = 50.4
L
(17)
N = 30
Y = 67.4
M

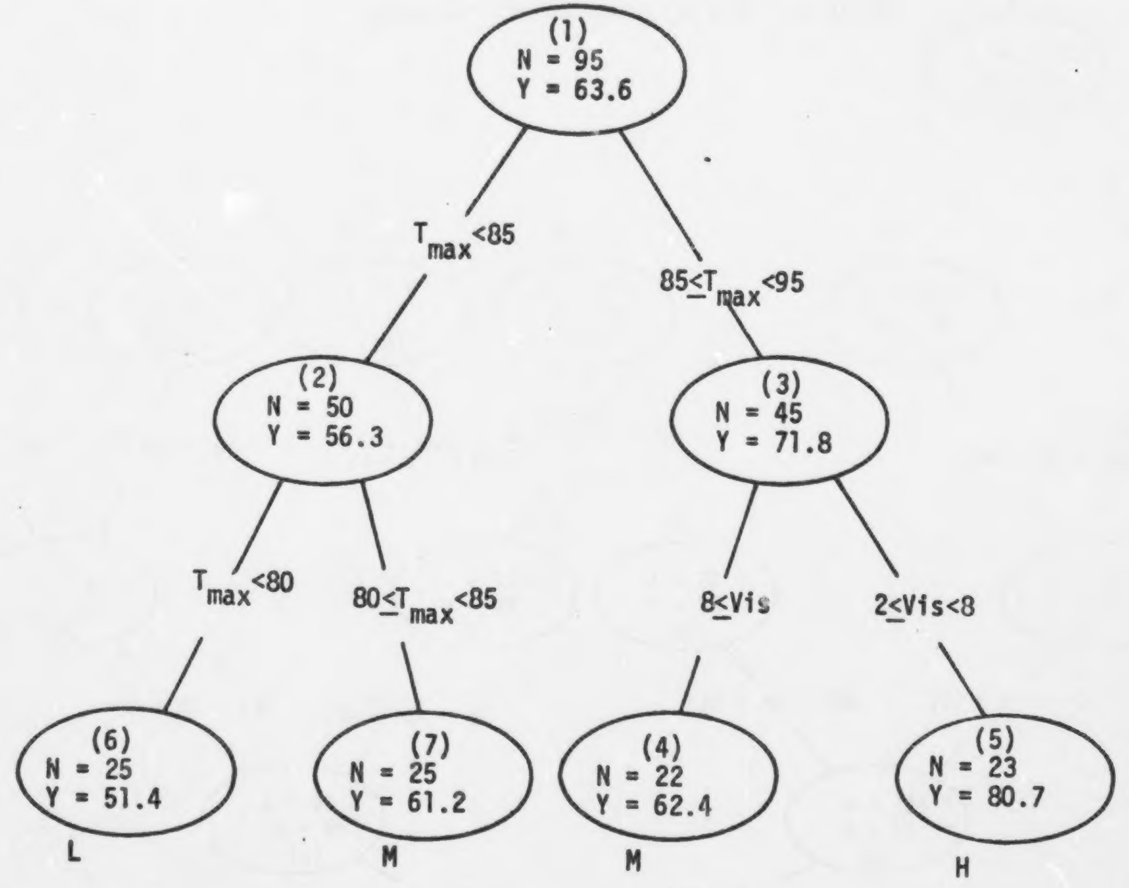
Camden, New Jersey (P.V.E. = 50.8%)


(1)
N = 161
Y = 74.5
T_max<75
75≤T_max
(2)
N = 39
Y = 47.5
L
(3)
N = 122
Y = 83.1
-45≤WD<240
240≤WD<-45
(4)
N = 88
Y = 76.0
(5)
N = 34
Y = 101.6
H
MH<1250
1250≤MH
(6)
N = 35
Y = 67.0
L
(7)
N = 53
Y = 81.9
M

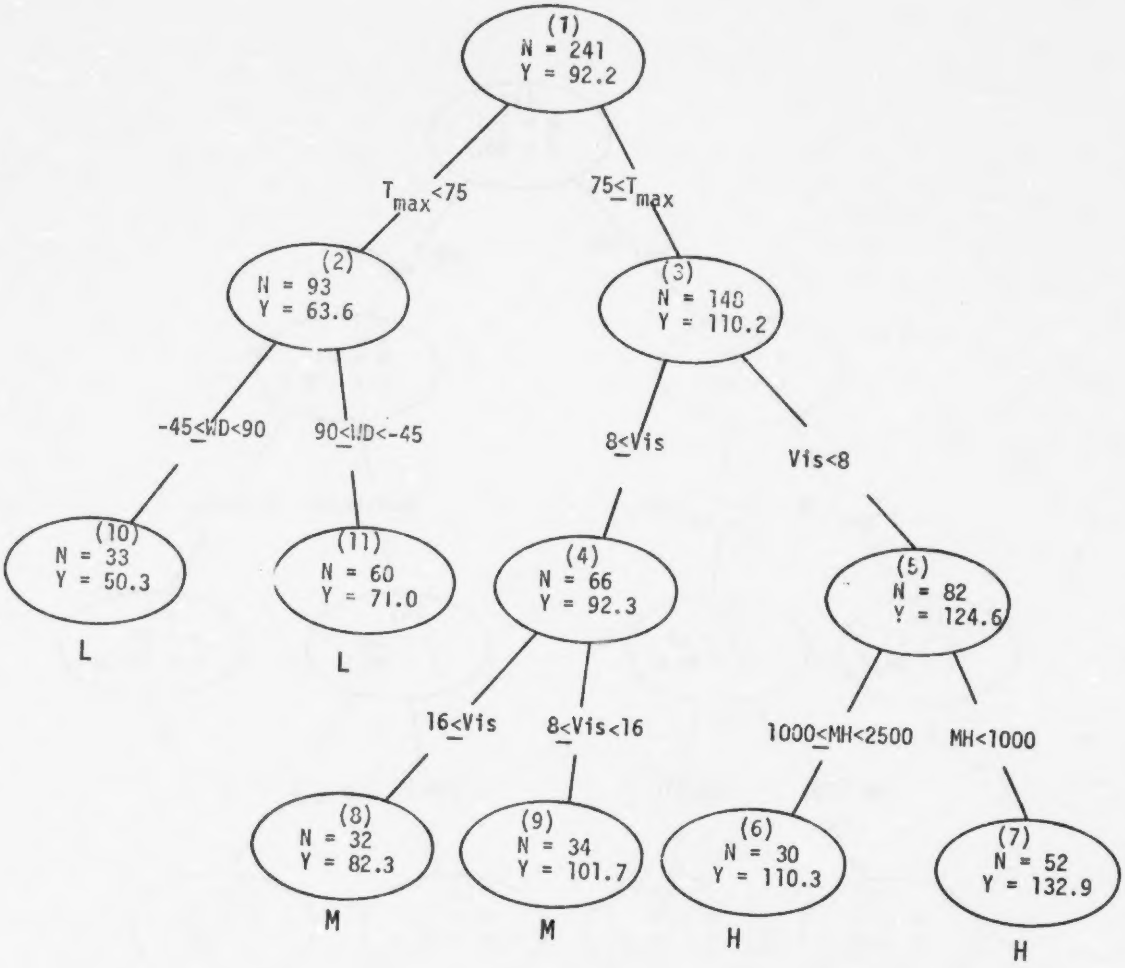
Camden Co., New Jersey (P.V.E. = 31.7%)


(1)
N = 175
Y = 87.4
8 ≤ Vis
Vis < 8
(2)
N = 88
Y = 65.9
(3)
N = 87
Y = 109.2
-45 ≤ WD < 135
135 ≤ WD < -45
-45 ≤ WD < 135
135 ≤ WD < -45
(8)
N = 45
Y = 49.7
(9)
N = 43
Y = 82.9
(4)
N = 22
Y = 85.3
M
(5)
N = 65
Y = 117.3
10 ≤ WS
4 ≤ WS < 10
55 ≤ Tmax < 75
75 ≤ Tmax < 90
240 ≤ WD < -45
135 ≤ WD < 240
(14)
N = 19
Y = 36.8
L
(15)
N = 26
Y = 59.1
L
(10)
N = 16
Y = 54.6
L
(11)
N = 27
Y = 99.6
M
(6)
N = 20
Y = 95.0
M
(7)
N = 45
Y = 127.2
0 ≤ V̄ < 7
7 ≤ V̄ < 12
(12)
N = 30
Y = 117.7
H
(13)
N = 15
Y = 146.2
H

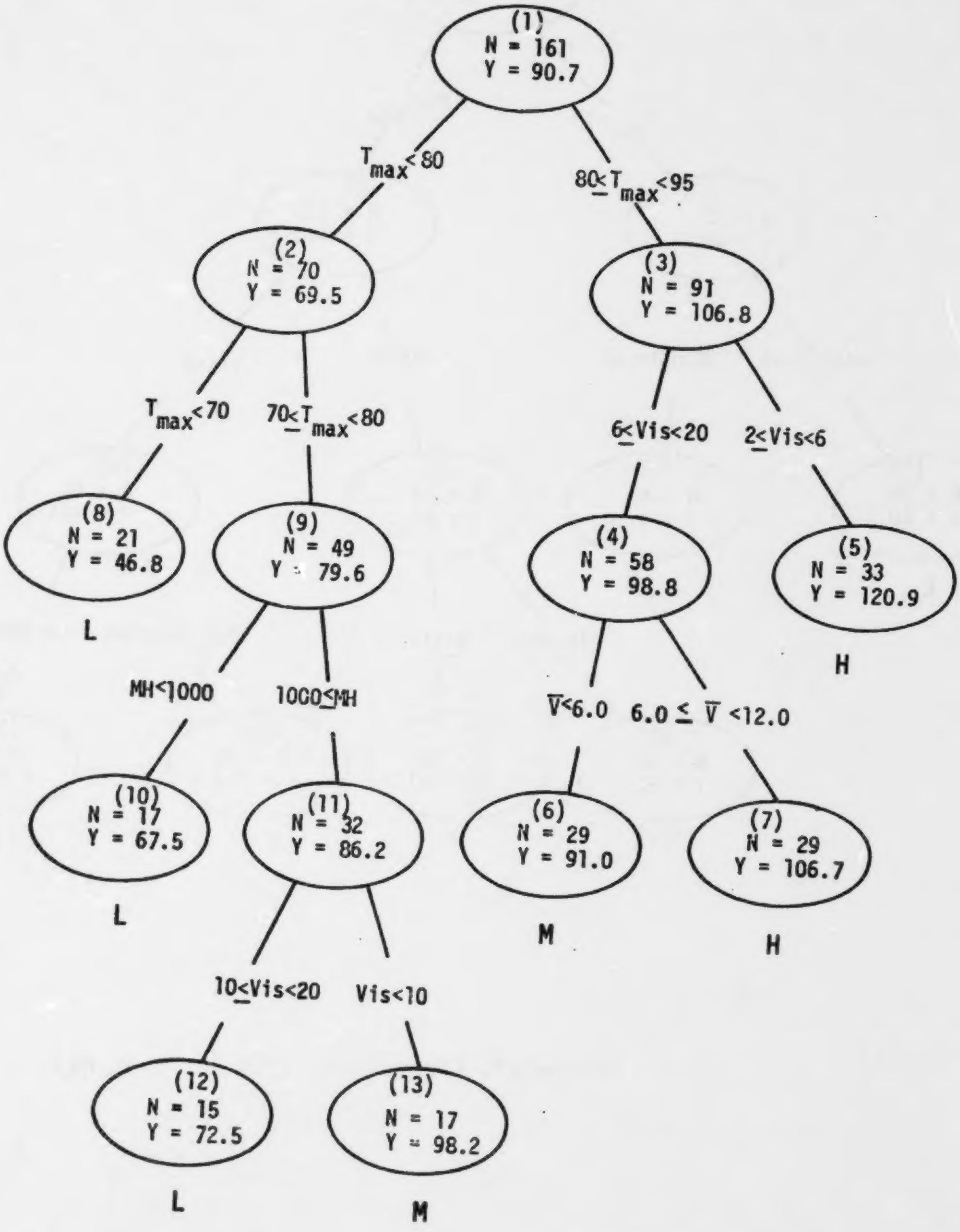
Danbury, Connecticut (P.V.E. = 39.8%)


(1)
N = 95
Y = 63.6
$T_{max}<85$
$85\leq T_{max}<95$
(2)
N = 50
Y = 56.3
(3)
N = 45
Y = 71.8
$T_{max}<80$
$80\leq T_{max}<85$
$8\leq Vis$
$2\leq Vis<8$
(6)
N = 25
Y = 51.4
L
(7)
N = 25
Y = 61.2
M
(4)
N = 22
Y = 62.4
M
(5)
N = 23
Y = 80.7
H

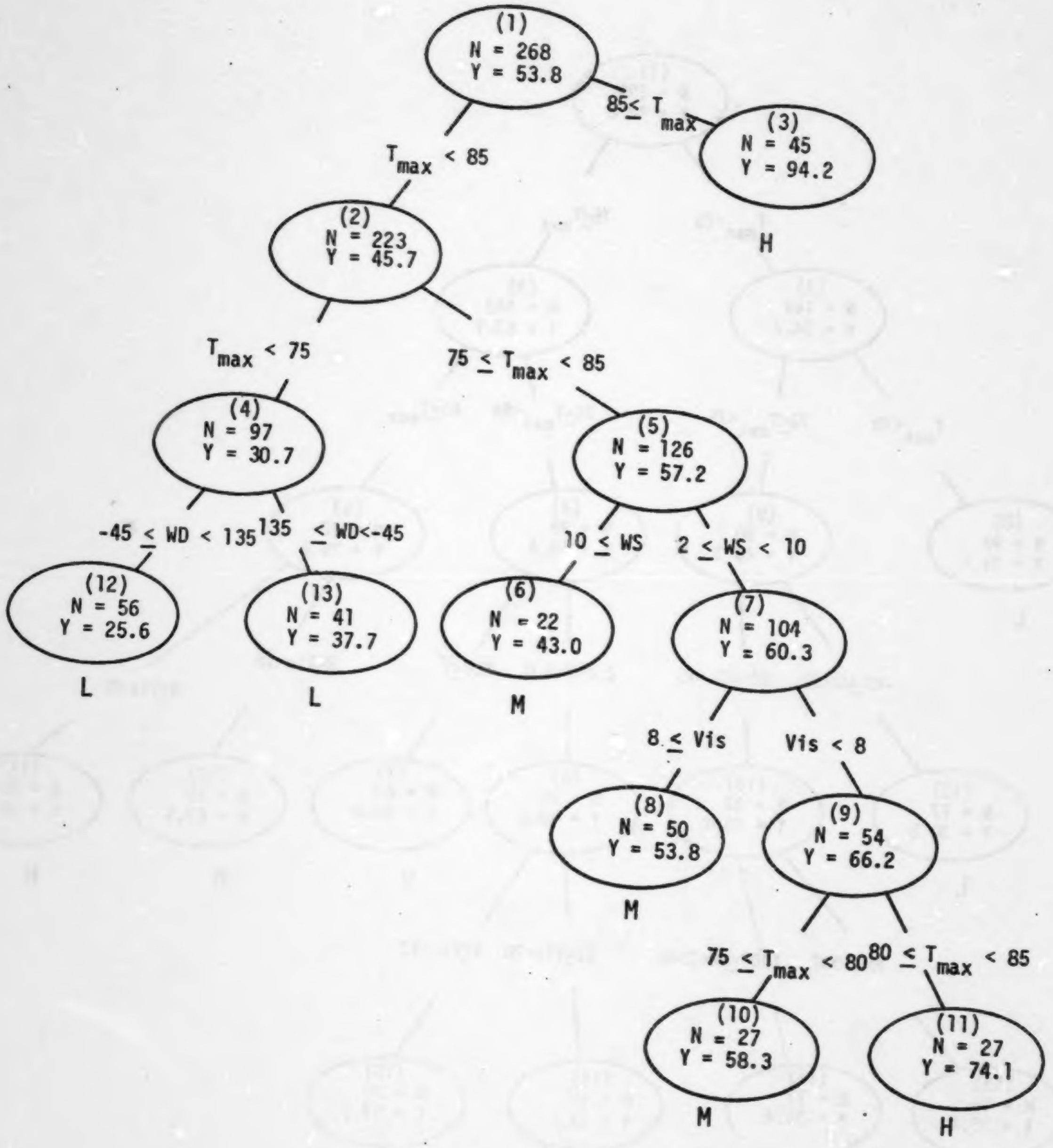
Gaithersburg, Md. (P.V.E. = 13.0%)


(1)
N = 241
Y = 92.2
T_{max}<75
75≤T_{max}
(2)
N = 93
Y = 63.6
(3)
N = 148
Y = 110.2
-45≤WD<90
90≤WD<-45
8≤Vis
Vis<8
(10)
N = 33
Y = 50.3
L
(11)
N = 60
Y = 71.0
L
(4)
N = 66
Y = 92.3
(5)
N = 82
Y = 124.6
16≤Vis
8≤Vis<16
1000≤MH<2500
MH<1000
(8)
N = 32
Y = 82.3
M
(9)
N = 34
Y = 101.7
M
(6)
N = 30
Y = 110.3
H
(7)
N = 52
Y = 132.9
H

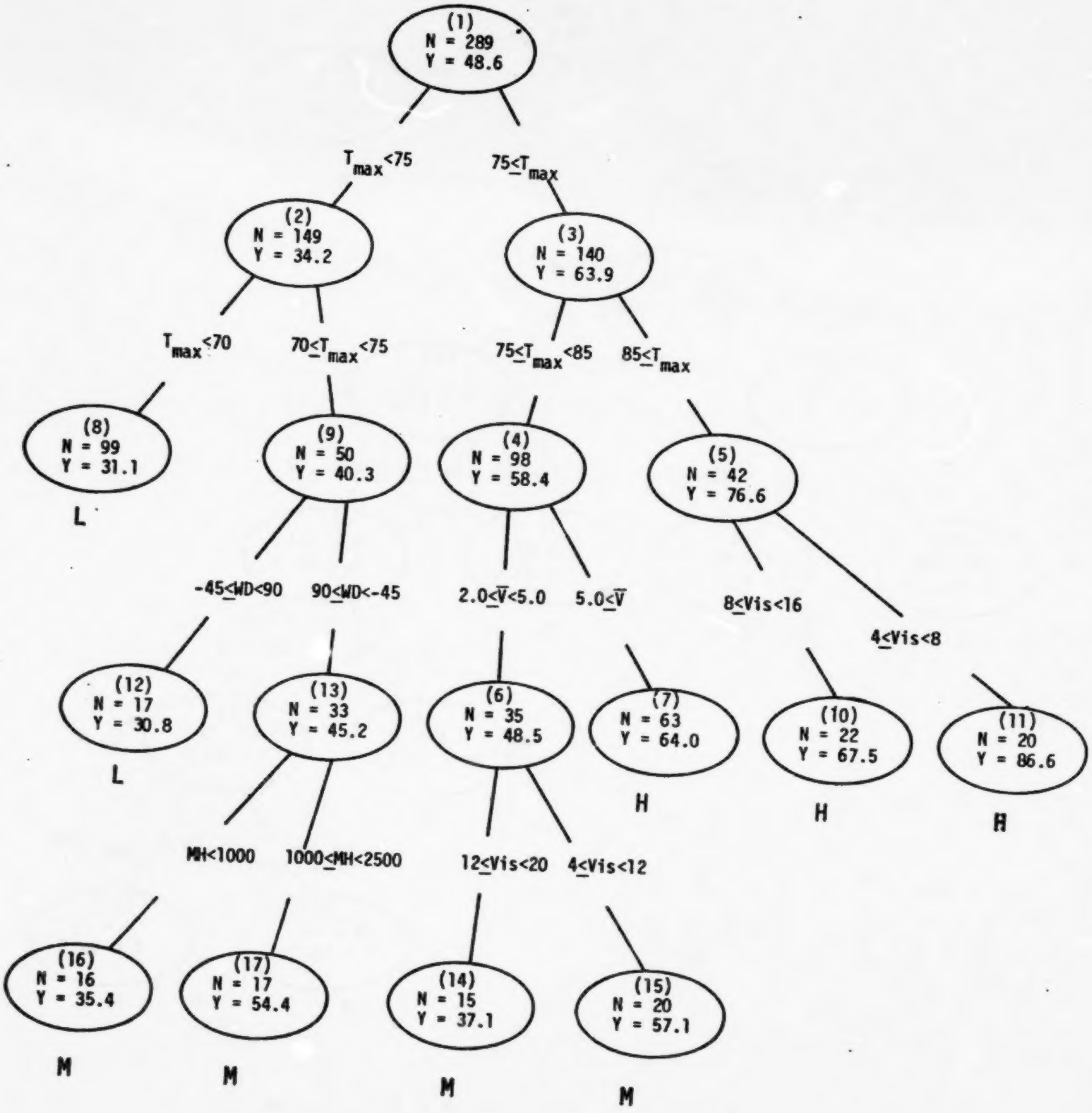
Greenwich, Connecticut (P.V.E. = 35.8%)


(1)
N = 161
Y = 90.7
T_max<80
80≤T_max<95
(2)
N = 70
Y = 69.5
(3)
N = 91
Y = 106.8
T_max<70
70≤T_max<80
6≤Vis<20
2≤Vis<6
(8)
N = 21
Y = 46.8
L
(9)
N = 49
Y = 79.6
(4)
N = 58
Y = 98.8
(5)
N = 33
Y = 120.9
H
MH<1000
1000≤MH
V̄<6.0
6.0 ≤ V̄ <12.0
(10)
N = 17
Y = 67.5
L
(11)
N = 32
Y = 86.2
(6)
N = 29
Y = 91.0
M
(7)
N = 29
Y = 106.7
H
10≤Vis<20
Vis<10
(12)
N = 15
Y = 72.5
L
(13)
N = 17
Y = 98.2
M

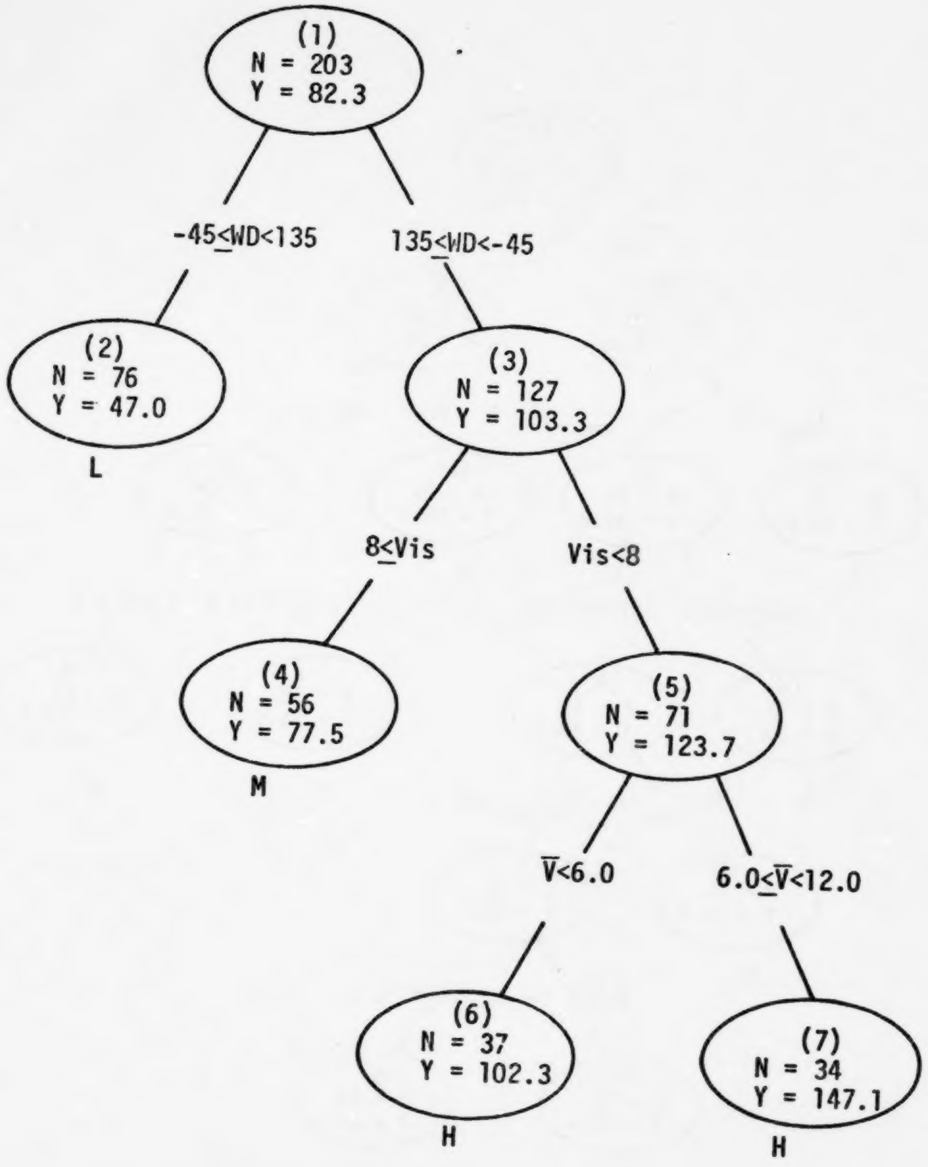
Lancaster, Pa. (P.V.E. = 45.8%)


(1)
N = 268
Y = 53.8
85 ≤ Tmax
(3)
N = 45
Y = 94.2
H
Tmax < 85
(2)
N = 223
Y = 45.7
Tmax < 75
75 ≤ Tmax < 85
(4)
N = 97
Y = 30.7
(5)
N = 126
Y = 57.2
-45 ≤ WD < 135
135 ≤ WD<-45
10 ≤ WS
2 ≤ WS < 10
(12)
N = 56
Y = 25.6
L
(13)
N = 41
Y = 37.7
L
(6)
N = 22
Y = 43.0
M
(7)
N = 104
Y = 60.3
8 ≤ Vis
Vis < 8
(8)
N = 50
Y = 53.8
M
(9)
N = 54
Y = 66.2
75 ≤ Tmax < 80
80 ≤ Tmax < 85
(10)
N = 27
Y = 58.3
M
(11)
N = 27
Y = 74.1
H

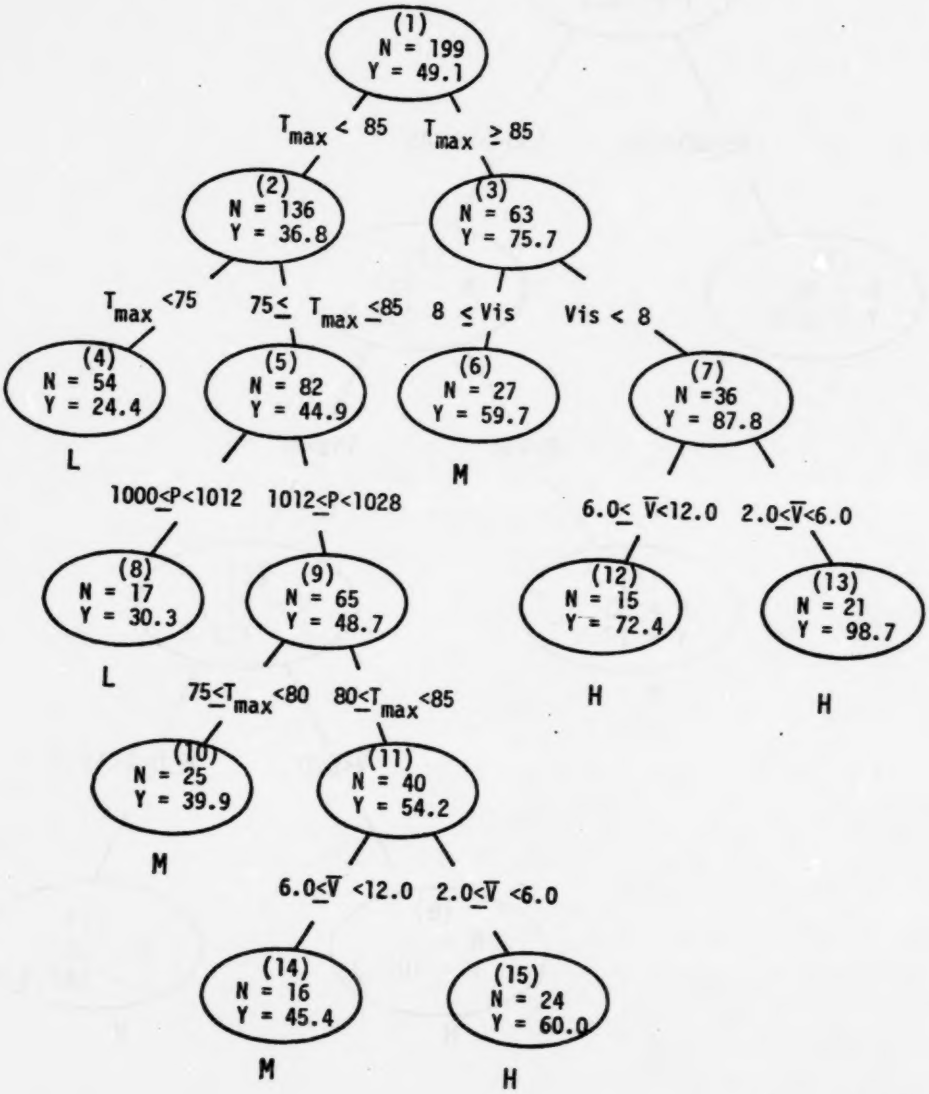
Mamaroneck, New York (P.V.E. = 49.3%)


(1)
N = 289
Y = 48.6
T_{max}<75
75≤T_{max}
(2)
N = 149
Y = 34.2
(3)
N = 140
Y = 63.9
T_{max}<70
70≤T_{max}<75
75≤T_{max}<85
85≤T_{max}
(8)
N = 99
Y = 31.1
L
(9)
N = 50
Y = 40.3
(4)
N = 98
Y = 58.4
(5)
N = 42
Y = 76.6
-45≤WD<90
90≤WD<-45
2.0≤$\overline{V}$<5.0
5.0≤$\overline{V}$
8≤Vis<16
4≤Vis<8
(12)
N = 17
Y = 30.8
L
(13)
N = 33
Y = 45.2
(6)
N = 35
Y = 48.5
(7)
N = 63
Y = 64.0
H
(10)
N = 22
Y = 67.5
H
(11)
N = 20
Y = 86.6
H
MH<1000
1000≤MH<2500
12≤Vis<20
4≤Vis<12
(16)
N = 16
Y = 35.4
M
(17)
N = 17
Y = 54.4
M
(14)
N = 15
Y = 37.1
M
(15)
N = 20
Y = 57.1
M

Medford, Mass. (P.Y.E. = 34.7%)

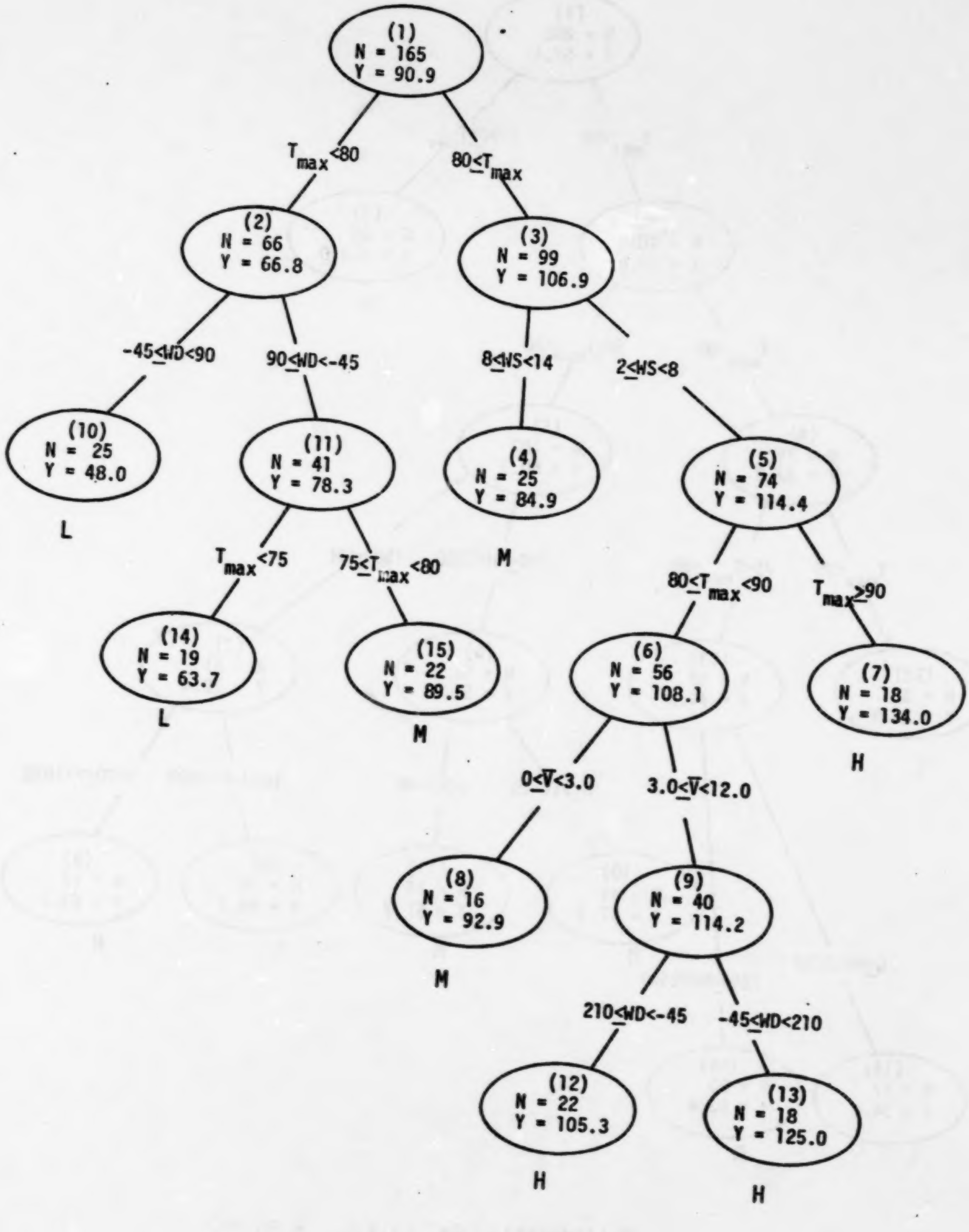

(1)
N = 203
Y = 82.3
-45≤WD<135
135≤WD<-45
(2)
N = 76
Y = 47.0
L
(3)
N = 127
Y = 103.3
8≤Vis
Vis<8
(4)
N = 56
Y = 77.5
M
(5)
N = 71
Y = 123.7
V̄<6.0
6.0≤V̄<12.0
(6)
N = 37
Y = 102.3
H
(7)
N = 34
Y = 147.1
H

Middletown, Conn. (P.V.E. = 42.5%)

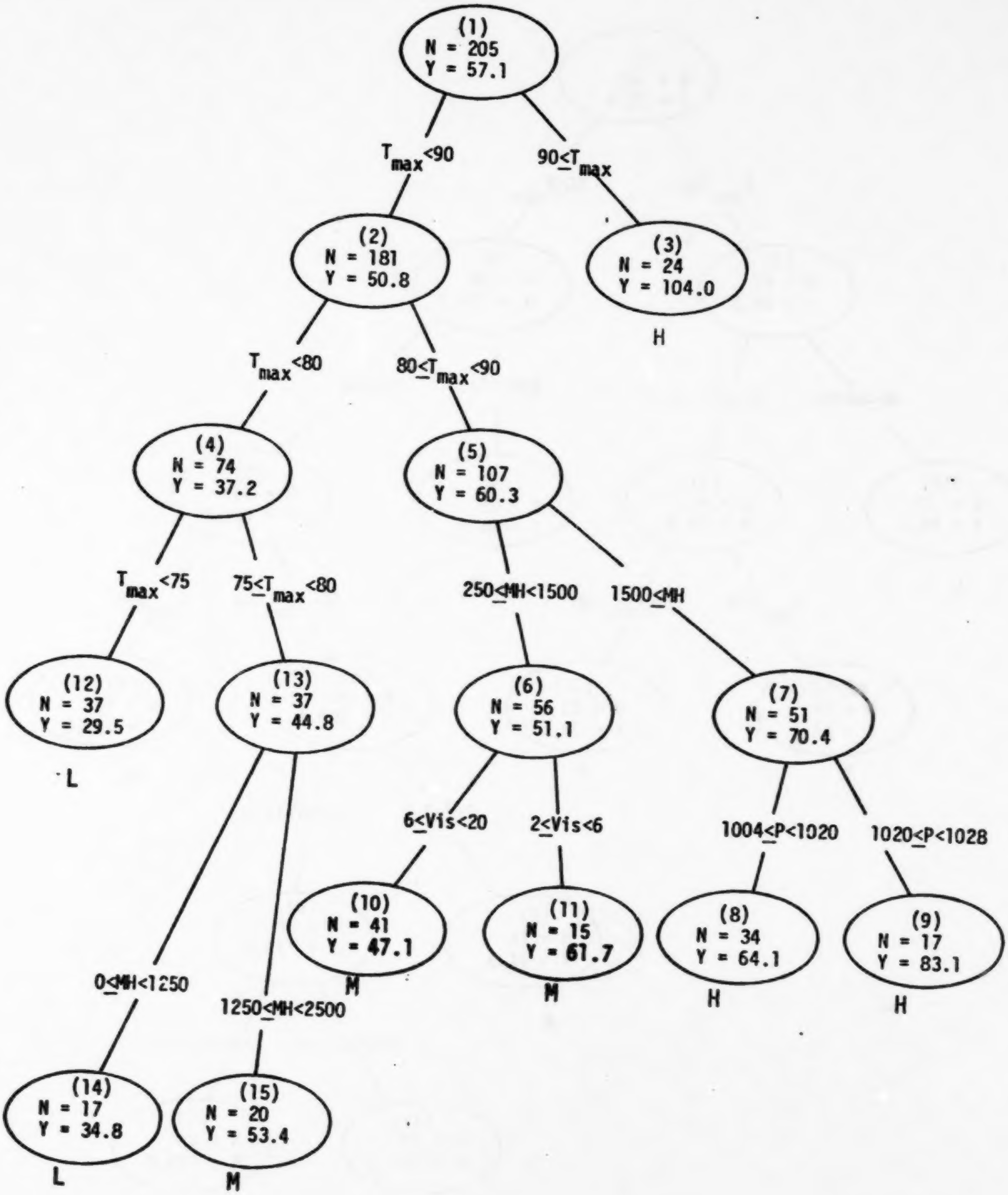


(1) N = 199 Y = 49.1
$T_{max} < 85$
$T_{max} \geq 85$
(2) N = 136 Y = 36.8
(3) N = 63 Y = 75.7
$T_{max} < 75$
$75 \leq T_{max} \leq 85$
$8 \leq Vis$
$Vis < 8$
(4) N = 54 Y = 24.4
L
(5) N = 82 Y = 44.9
(6) N = 27 Y = 59.7
M
(7) N = 36 Y = 87.8
$1000 \leq P < 1012$
$1012 \leq P < 1028$
$6.0 \leq \bar{V} < 12.0$
$2.0 \leq \bar{V} < 6.0$
(8) N = 17 Y = 30.3
L
(9) N = 65 Y = 48.7
(12) N = 15 Y = 72.4
H
(13) N = 21 Y = 98.7
H
$75 \leq T_{max} < 80$
$80 \leq T_{max} < 85$
(10) N = 25 Y = 39.9
M
(11) N = 40 Y = 54.2
$6.0 \leq \bar{V} < 12.0$
$2.0 \leq \bar{V} < 6.0$
(14) N = 16 Y = 45.4
M
(15) N = 24 Y = 60.0
H

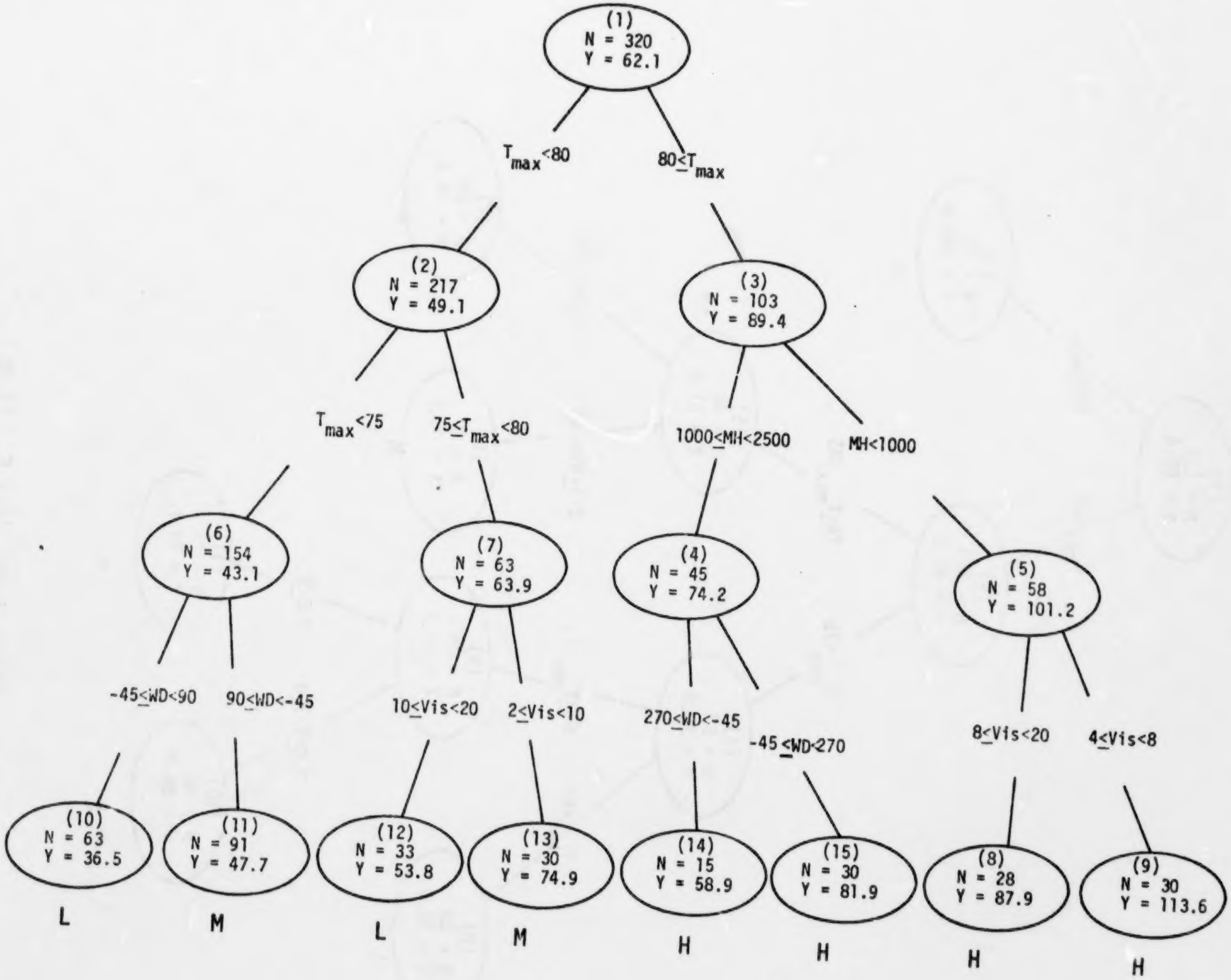
Newark, New Jersey (P.V.E. = 54.4%)


(1) N = 165 Y = 90.9
$T_{max} < 80$
$80 \le T_{max}$
(2) N = 66 Y = 66.8
(3) N = 99 Y = 106.9
$-45 \le WD < 90$
$90 \le WD < -45$
$8 \le WS < 14$
$2 \le WS < 8$
(10) N = 25 Y = 48.0
L
(11) N = 41 Y = 78.3
(4) N = 25 Y = 84.9
M
(5) N = 74 Y = 114.4
$T_{max} < 75$
$75 \le T_{max} < 80$
$80 \le T_{max} < 90$
$T_{max} \ge 90$
(14) N = 19 Y = 63.7
L
(15) N = 22 Y = 89.5
M
(6) N = 56 Y = 108.1
(7) N = 18 Y = 134.0
H
$0 \le \overline{V} < 3.0$
$3.0 \le \overline{V} < 12.0$
(8) N = 16 Y = 92.9
M
(9) N = 40 Y = 114.2
$210 \le WD < -45$
$-45 \le WD < 210$
(12) N = 22 Y = 105.3
H
(13) N = 18 Y = 125.0
H

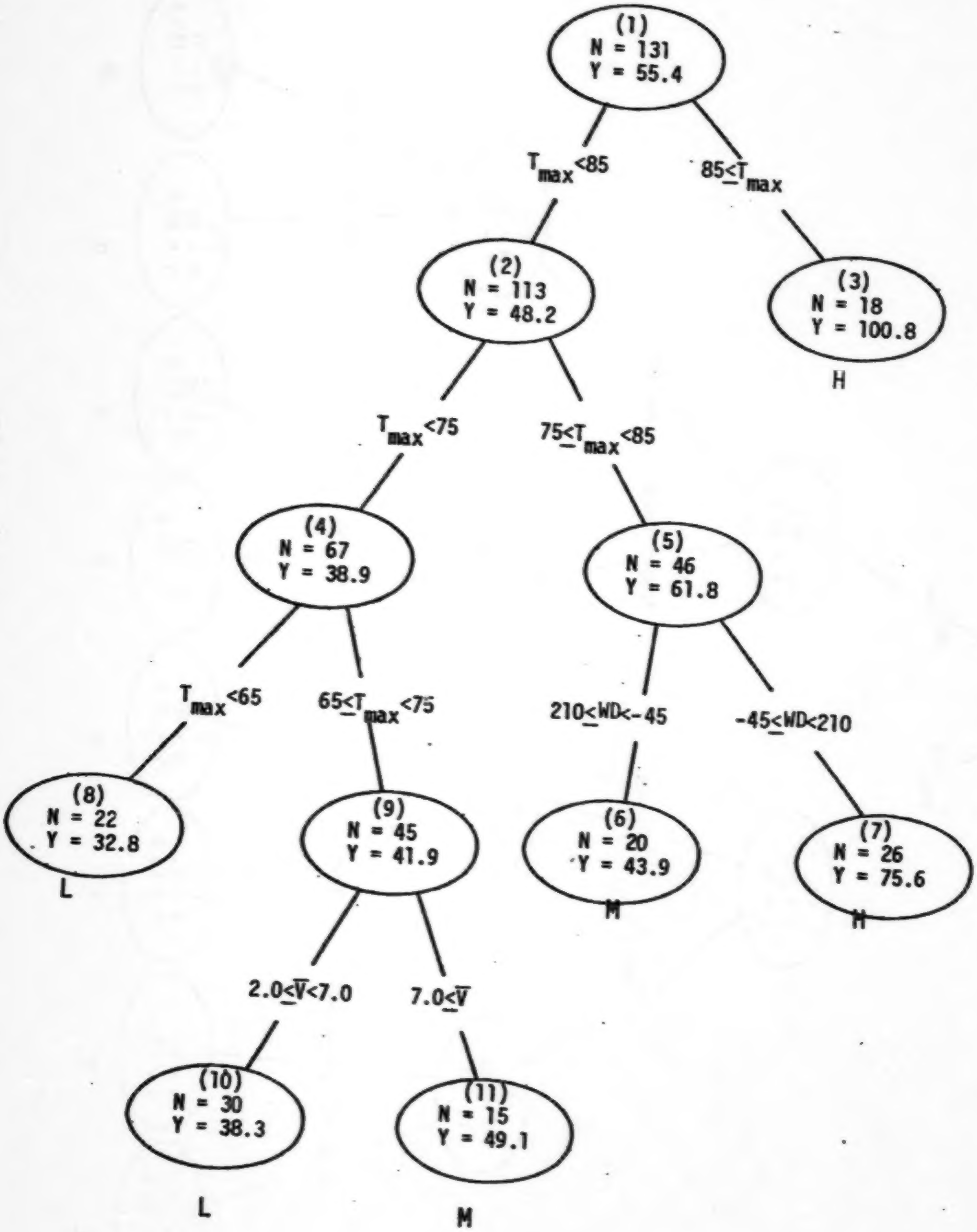
Norristown, Pa. (P.V.E. = 48.4%)


(1)
N = 205
Y = 57.1
$T_{max}<90$
$90 \le T_{max}$
(2)
N = 181
Y = 50.8
(3)
N = 24
Y = 104.0
H
$T_{max}<80$
$80 \le T_{max}<90$
(4)
N = 74
Y = 37.2
(5)
N = 107
Y = 60.3
$T_{max}<75$
$75 \le T_{max}<80$
$250 \le MH<1500$
$1500 \le MH$
(12)
N = 37
Y = 29.5
L
(13)
N = 37
Y = 44.8
(6)
N = 56
Y = 51.1
(7)
N = 51
Y = 70.4
$6 \le Vis<20$
$2 \le Vis<6$
$1004 \le P<1020$
$1020 \le P<1028$
(10)
N = 41
Y = 47.1
M
(11)
N = 15
Y = 61.7
M
(8)
N = 34
Y = 64.1
H
(9)
N = 17
Y = 83.1
H
$0 \le MH<1250$
$1250 \le MH<2500$
(14)
N = 17
Y = 34.8
L
(15)
N = 20
Y = 53.4
M

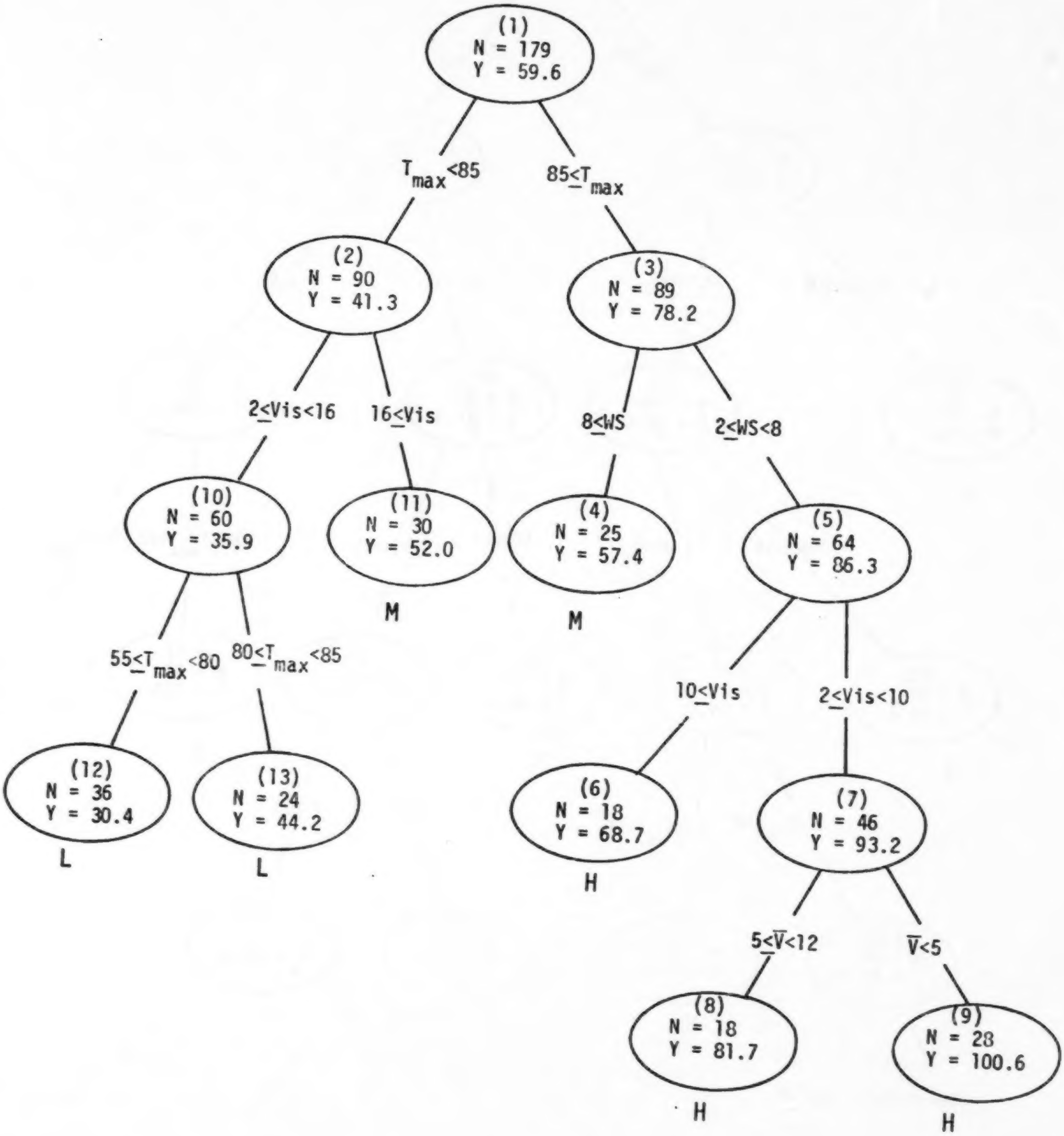
Philadelphia, Pa. (P.V.E. = 50.0%)


(1) N = 320 Y = 62.1
$T_{max}<80$
$80\leq T_{max}$
(2) N = 217 Y = 49.1
(3) N = 103 Y = 89.4
$T_{max}<75$
$75\leq T_{max}<80$
$1000\leq MH<2500$
$MH<1000$
(6) N = 154 Y = 43.1
(7) N = 63 Y = 63.9
(4) N = 45 Y = 74.2
(5) N = 58 Y = 101.2
$-45\leq WD<90$
$90\leq WD<-45$
$10\leq Vis<20$
$2\leq Vis<10$
$270\leq WD<-45$
$-45\leq WD<270$
$8\leq Vis<20$
$4\leq Vis<8$
(10) N = 63 Y = 36.5
(11) N = 91 Y = 47.7
(12) N = 33 Y = 53.8
(13) N = 30 Y = 74.9
(14) N = 15 Y = 58.9
(15) N = 30 Y = 81.9
(8) N = 28 Y = 87.9
(9) N = 30 Y = 113.6
L
M
L
M
H
H
H
H

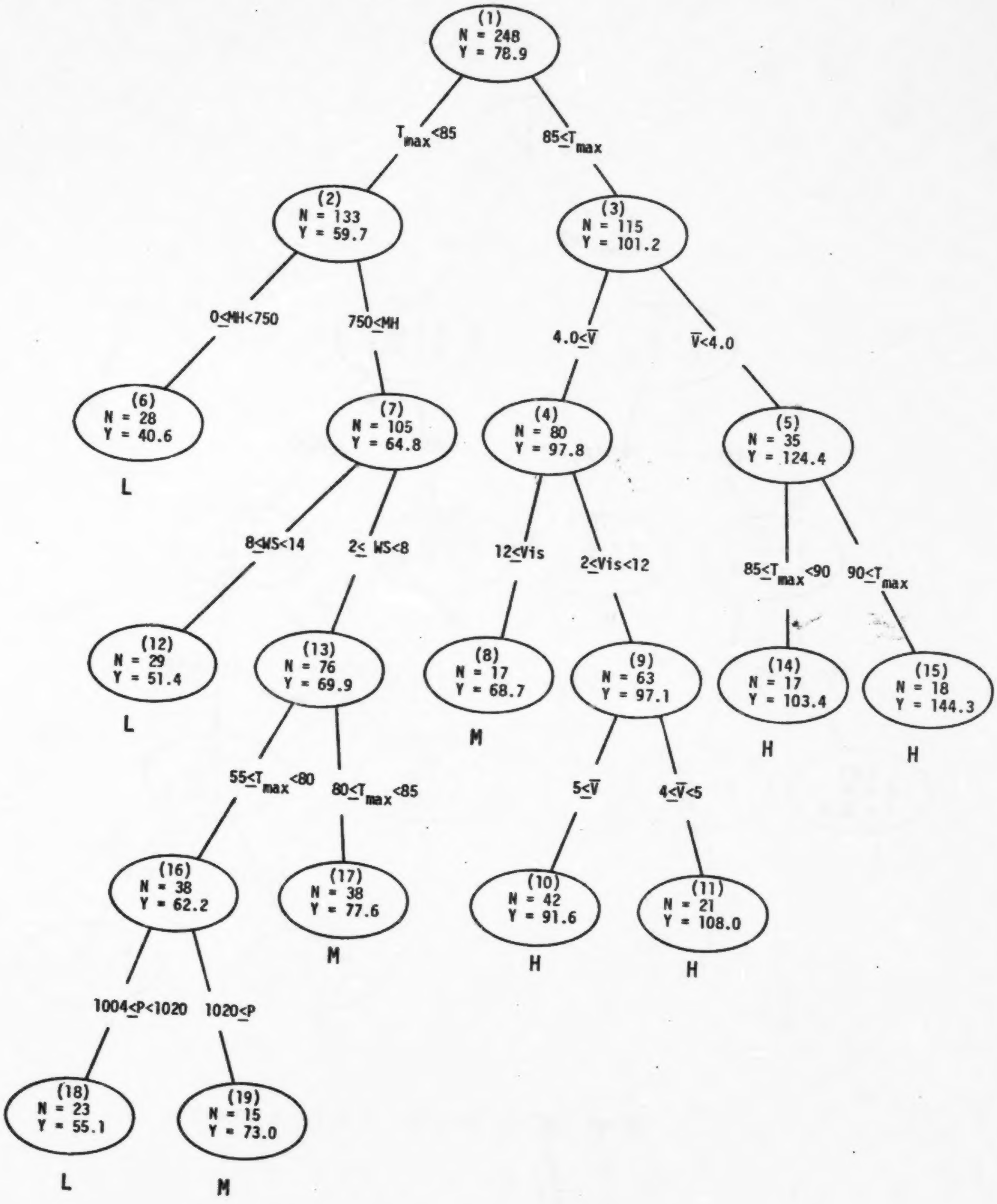
Quincy, Mass. (P.V.E. = 44.8%)


(1)
N = 131
Y = 55.4
$T_{max}<85$
$85 \le T_{max}$
(2)
N = 113
Y = 48.2
(3)
N = 18
Y = 100.8
H
$T_{max}<75$
$75 \le T_{max}<85$
(4)
N = 67
Y = 38.9
(5)
N = 46
Y = 61.8
$T_{max}<65$
$65 \le T_{max}<75$
$210 \le WD<-45$
$-45 \le WD<210$
(8)
N = 22
Y = 32.8
L
(9)
N = 45
Y = 41.9
(6)
N = 20
Y = 43.9
M
(7)
N = 26
Y = 75.6
H
$2.0 \le \overline{V}<7.0$
$7.0 \le \overline{V}$
(10)
N = 30
Y = 38.3
L
(11)
N = 15
Y = 49.1
M

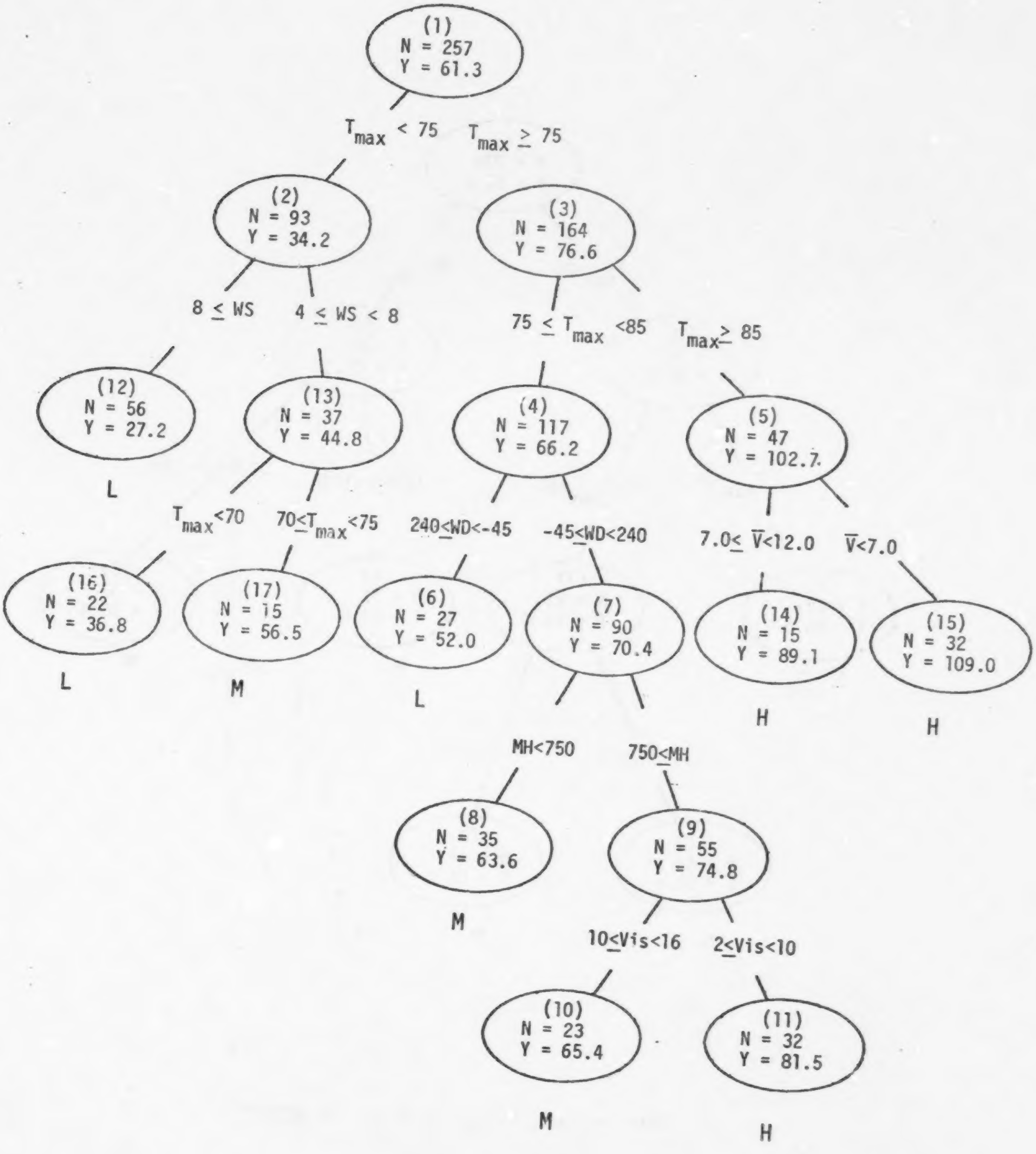
Salem, Mass. (P.V.E. = 49.2%)


(1)
N = 179
Y = 59.6
$T_{max}<85$
$85\leq T_{max}$
(2)
N = 90
Y = 41.3
(3)
N = 89
Y = 78.2
$2\leq Vis<16$
$16\leq Vis$
$8\leq WS$
$2\leq WS<8$
(10)
N = 60
Y = 35.9
(11)
N = 30
Y = 52.0
M
(4)
N = 25
Y = 57.4
M
(5)
N = 64
Y = 86.3
$55\leq T_{max}<80$
$80\leq T_{max}<85$
$10\leq Vis$
$2\leq Vis<10$
(12)
N = 36
Y = 30.4
L
(13)
N = 24
Y = 44.2
L
(6)
N = 18
Y = 68.7
H
(7)
N = 46
Y = 93.2
$5\leq \overline{V}<12$
$\overline{V}<5$
(8)
N = 18
Y = 81.7
H
(9)
N = 28
Y = 100.6
H

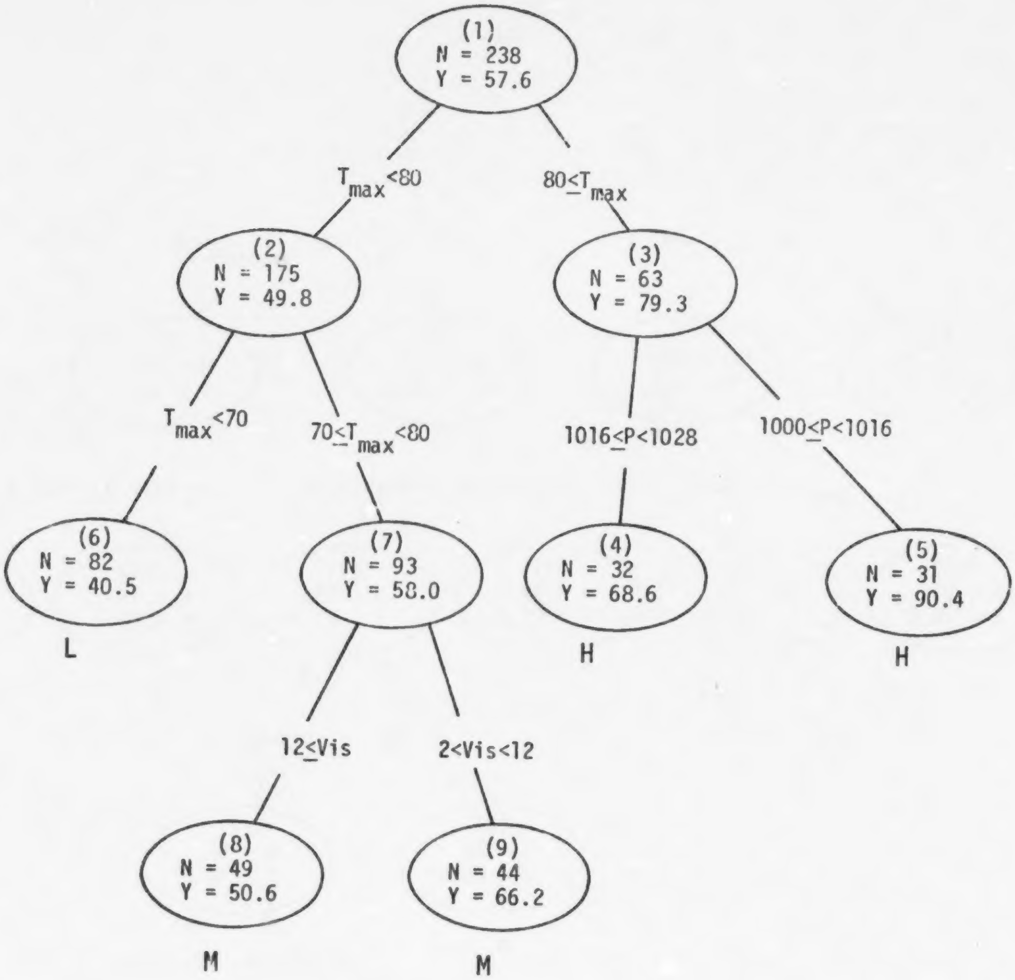
Silver Spring, Maryland (P.V.E. = 40.6%)


(1)
N = 248
Y = 78.9
$T_{max}<85$
$85\leq T_{max}$
(2)
N = 133
Y = 59.7
(3)
N = 115
Y = 101.2
$0\leq MH<750$
$750\leq MH$
$4.0\leq \overline{V}$
$\overline{V}<4.0$
(6)
N = 28
Y = 40.6
L
(7)
N = 105
Y = 64.8
(4)
N = 80
Y = 97.8
(5)
N = 35
Y = 124.4
$8\leq WS<14$
$2\leq WS<8$
$12\leq Vis$
$2\leq Vis<12$
$85\leq T_{max}<90$
$90\leq T_{max}$
(12)
N = 29
Y = 51.4
L
(13)
N = 76
Y = 69.9
(8)
N = 17
Y = 68.7
M
(9)
N = 63
Y = 97.1
(14)
N = 17
Y = 103.4
H
(15)
N = 18
Y = 144.3
H
$55\leq T_{max}<80$
$80\leq T_{max}<85$
$5\leq \overline{V}$
$4\leq \overline{V}<5$
(16)
N = 38
Y = 62.2
(17)
N = 38
Y = 77.6
M
(10)
N = 42
Y = 91.6
H
(11)
N = 21
Y = 108.0
H
$1004\leq P<1020$
$1020\leq P$
(18)
N = 23
Y = 55.1
L
(19)
N = 15
Y = 73.0
M

Suitland Parkway, Md.


(1)
N = 257
Y = 61.3
T_max < 75
T_max ≥ 75
(2)
N = 93
Y = 34.2
(3)
N = 164
Y = 76.6
8 ≤ WS
4 ≤ WS < 8
75 ≤ T_max <85
T_max ≥ 85
(12)
N = 56
Y = 27.2
L
(13)
N = 37
Y = 44.8
(4)
N = 117
Y = 66.2
(5)
N = 47
Y = 102.7
T_max<70
70≤T_max<75
240≤WD<-45
-45≤WD<240
7.0≤ V̄<12.0
V̄<7.0
(16)
N = 22
Y = 36.8
L
(17)
N = 15
Y = 56.5
M
(6)
N = 27
Y = 52.0
L
(7)
N = 90
Y = 70.4
(14)
N = 15
Y = 89.1
H
(15)
N = 32
Y = 109.0
H
MH<750
750≤MH
(8)
N = 35
Y = 63.6
M
(9)
N = 55
Y = 74.8
10≤Vis<16
2≤Vis<10
(10)
N = 23
Y = 65.4
M
(11)
N = 32
Y = 81.5
H

Welfare Is., New York (P.V.E. = 54.9%)


(1)
N = 238
Y = 57.6
$T_{max} < 80$
$80 \le T_{max}$
(2)
N = 175
Y = 49.8
(3)
N = 63
Y = 79.3
$T_{max} < 70$
$70 \le T_{max} < 80$
$1016 \le P < 1028$
$1000 \le P < 1016$
(6)
N = 82
Y = 40.5
L
(7)
N = 93
Y = 58.0
(4)
N = 32
Y = 68.6
H
(5)
N = 31
Y = 90.4
H
$12 \le Vis$
$2 < Vis < 12$
(8)
N = 49
Y = 50.6
M
(9)
N = 44
Y = 66.2
M

Worchester, Mass. (P.V.E. = 26.2%)

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